This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

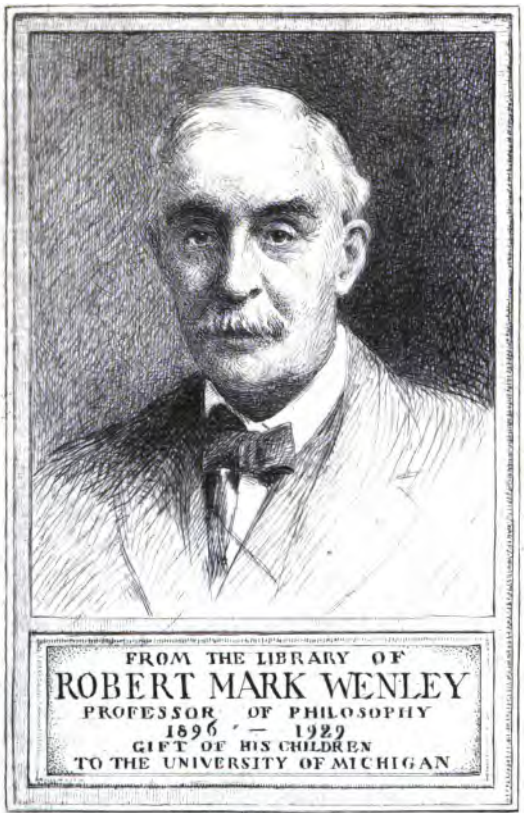
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`



FROM THE LIBRARY OF
ROBERT MARK WENLEY
PROFESSOR OF PHILOSOPHY
1896 — 1929
GIFT OF HIS CHILDREN
TO THE UNIVERSITY OF MICHIGAN

W.H.W. Jackson del. et sc.
1938

UNIVERSITY EXTENSION SERIES

EDITED BY J. E. SYMES, M.A.,
Principal of University College, Nottingham.

THE CHEMISTRY OF LIFE AND HEALTH

University Extension Series.

UNDER the above title MESSRS METHUEN are publishing a series of books on Historical, Literary, and Scientific subjects. The University Extension Movement has shown the possibility of treating History, Literature, and Science in a way that is at once popular and scholarly. The writers in this series aim at a similar combination. Each volume will be complete in itself, and the subjects will be treated by competent writers in a broad and philosophic spirit.

Crown 8vo, 2s. 6d.

The following Volumes are ready:—

1. **THE INDUSTRIAL HISTORY OF ENGLAND.** H. DE B. GIBBINS, M.A. *Second Edition Revised.* With Maps and Plans.
2. **A HISTORY OF POLITICAL ECONOMY IN ENGLAND: from Adam Smith to Arnold Toynbee.** L. L. PRICE, M.A.
3. **PROBLEMS OF POVERTY. An Inquiry into the Industrial Conditions of the Poor.** J. A. HOBSON, M.A.
4. **VICTORIAN POETS.** AMY SHARP, Newnham College, Cambridge.
5. **PSYCHOLOGY.** F. S. GRANGER, M.A.
6. **THE EVOLUTION OF PLANT LIFE: Lower Forms. An Introduction to the Study of Cryptogamic Botany.** G. MASSEE.
7. **THE FRENCH REVOLUTION.** J. E. SYMES, M.A., Principal of University College, Nottingham. With Map of France.
8. **AIR AND WATER.** Professor V. B. LEWES, M.A. Illustrated.
9. **ENGLISH SOCIAL REFORMERS.** H. DE B. GIBBINS, M.A.
10. **ENGLISH TRADE AND FINANCE IN THE SEVENTEENTH CENTURY.** W. A. S. HEWINS, B.A.
11. **AGRICULTURAL BOTANY.** M. C. POTTER, M.A. Illustrated. *[In the Press.*
12. **ELECTRICITY.** G. J. BURCH, M.A. Illustrated. *[In the Press.*
13. **THE MECHANICS OF DAILY LIFE.** V. P. SELLS, M.A. Illustrated.

The following Volumes are in preparation:—

ENGLISH PAINTERS. D. S. MACCOLL, M.A., Fellow of University College, London, U. E. Lecturer in Art and Literature.

THE PRE-SHAKSPERIAN DRAMA. H. M. FITZGIBBON, M.A.

THE EARTH. An Introduction to Physiography. E. W. SMALL, M.A.

AGRICULTURAL CHEMISTRY. M. J. R. DUNSTAN, M.A.

THE ITALIAN REPUBLICS (1250-1530). OSCAR BROWNING, M.A.

METHUEN & CO., 18 BURY STREET, W.C.

THE CHEMISTRY

OF

LIFE AND HEALTH

BY

C. W. KIMMINS, M.A., D.Sc.,

Staff Lecturer in Chemistry, Cambridge University Extension Scheme.

ILLUSTRATED

Methuen & Co.

18 BURY STREET, LONDON, W.C.

1892

[*All rights reserved.*]

QH
345
.K49

gt-worley lib
5-18-39

PREFACE.

THE vast importance of the study of the Laws of Health is becoming so generally recognised that in the future no System of Education will be considered complete which does not embrace this subject in its curriculum.

Great difficulties, however, present themselves to the average reader of works on Hygiene, because an acquaintance with various branches of Natural Science is necessary in order to follow intelligently certain portions of such books. Thus it is impossible to understand clearly the important changes going on in respiration without some knowledge of the structure of the lungs, and the nature of the gases taking part in the process.

I have endeavoured in this little book to remove these difficulties by giving sufficient information on the particular portions of the sciences involved to enable readers, other than experts, to appreciate fully the fundamental principles of Hygiene.

Considerable prominence has been given to the chemical changes which play such an important part in questions of Life and Health, and also to the impurities which occur in air, water, and articles of diet, and the methods which should be adopted for their detection.

For a more detailed account of the subject I must refer my readers to Parkes' "Manual of Practical Hygiene"

(7th Edition); Louis Parkes' "Hygiene and Public Health;" Smith's "Foods" (International Series); and Yeo's "Food in Health and Disease."

I must, in conclusion, thank Dr Major Brown of Spondon for suggestions and assistance in correcting proofs, and Messrs Whittingham & Co. for a few of the illustrations in Professor Lewes' excellent book on "Air and Water," published in this series.

DOWNING COLLEGE, CAMBRIDGE,
October 1892.

CONTENTS.

CHAPTER I.

THE PRINCIPLES OF CHEMISTRY.

PAGE

Distinction between Chemistry and Physics—Indestructibility of Matter—Elements, Compounds, and Mixtures—Atoms and Molecules—Avogadro's Law—Molecular Weights—Chemical Symbols—Formulæ—Equations—Weights and Measures 1

CHAPTER II.

THE ATMOSPHERE.

Pressure — Extent of Atmosphere — Chemical Composition — Composition by Weight — Composition by Volume — The Functions of Oxygen and Nitrogen—Preparation and Properties of Oxygen—Combustion—Preparation and Properties of Nitrogen — Carbonic Acid — Aqueous Vapour — Air a Mixture 17

CHAPTER III.

CARBON AND ITS COMPOUNDS.

Carbon—Allotropic Modifications—Action of Charcoal on Obnoxious Gases—Action of Charcoal on Liquids—Compounds with Oxygen—Carbon Dioxide—Storage of Energy in Green Plants—Compounds with Oxygen—Carbon Monoxide—Compounds with Hydrogen—Coal Gas—The Constitution of Gases—Variations of the Volume of Gases with Changes of Temperature and Pressure—Diffusion of Gases . . 37

CHAPTER IV.

RESPIRATION.

PAGE

Function of Respiration—Mechanics of Respiration—Difference between Inspired and Expired Air—The Blood—Structure of Blood Vessels—Minute Structure of the Lungs—The Gaseous Interchange—Changes in the Blood—The Warmth of the Body—Suffocation 54

CHAPTER V.

VENTILATION.

The Atmosphere—Sources of Impurity—Purifying Agents—Vitiated Air—Breathing Space required—Estimation of Impurities in Air—Ventilation—Methods of Ventilation—The Effect of Vitiated Air on Health 67

CHAPTER VI.

WATER.

Hydrogen—Preparation and Properties—Water a Compound—Composition by Weight—Composition by Volume—Three States—Solid, Liquid, and Gaseous—Latent and Specific Heat—Changes in Volume—Importance of these in Nature—Solubility of Solids and Gases in Water—Hardness of Water—Organic Impurities in Water—Metallic Impurity in Water 84

CHAPTER VII.

THE SPREAD OF DISEASE BY IMPURE WATER—BACTERIA.

Epidemics and Impure Water—Malarial Fever—Enteric Fever—Cholera—Recognition of Impurity in Water—Natural Purification of Water—Artificial Purification of Water—Carbon Filters—Spongy Iron Filters—Nature of Bacteria—Action of Bacteria—Antiseptics—Bacteria in Air and Water—Importance of Bacteria in Nature . . . 102

CHAPTER VIII.

DIGESTION.

PAGE

Object of Digestion—The Digestive Apparatus—Classes of Food-Stuffs—Action of Saliva—Action of Gastric Juice—Action of Bile—Action of Pancreatic Juice—The Passage of Food into the Blood—The Daily Loss—Necessity for a Mixed Diet—The Effect of Cooking on Digestibility . . 118

CHAPTER IX.

BREAD AND MEAT AS ARTICLES OF DIET.

Composition of Bread—Varieties of Bread—Methods of Raising Bread—Adulteration of Bread and Methods of Detection—Composition of Meat—Methods of Cooking—Comparison of Animal and Vegetable Food—Flesh-formers and Body-warmers 133

CHAPTER X.

MILK, TEA, AND ALCOHOL AS ARTICLES OF DIET.

The Composition of Milk—Milk as a Food—Analysis of Milk—Adulteration of Milk, and Methods of Detection—Milk and the Spread of Disease—Composition of Tea—Physiological action of Tea—The Adulteration of Tea—Composition of Alcoholic Beverages—Physiological action of Alcohol—The action of Alcohol as a Food—Adulteration of Alcoholic Beverages 146

THE

CHEMISTRY OF LIFE AND HEALTH.

CHAPTER I.

THE PRINCIPLES OF CHEMISTRY.

1. **Distinction between Chemistry and Physics.** — Changes are continually taking place in matter; some of these changes are permanent, others are only temporary, in which case the matter reverts to its previous condition on the removal of the exciting cause of the change. The science of Chemistry has to deal with the former, and the science of Physics with the latter class of phenomena. The burning candle is an example of chemical change. In the process of burning the candle disappears and certain gases are produced which show no tendency, under any conditions, to revert to their former state. The electric lamp, on the other hand, is an example of physical change. The carbon filament glows only as long as the electric current passes through it. Switch off the current, and the filament returns to its natural condition, but on again bringing into play the exciting cause it glows as before.

When a clean poker is placed in the fire the metal undergoes a change and exhibits new properties. It can now

give out heat, and, if raised to a sufficiently high temperature, light. After removal from the fire it gradually loses these new properties and then it is impossible to detect the slightest change either in weight or in the nature of the material of which it is composed. If, however, the poker, when red-hot, is plunged into cold water, a colourless gas is given off, which will readily burn, and the poker is found to have undergone change both in weight and chemical nature, a portion of the iron having united with the oxygen of the water to form a coating of rust. The former change is physical, the latter chemical. *Chemistry can thus be defined as the science which deals with the permanent changes of matter.*

2. **Indestructibility of Matter.**—The law which states that matter, *though capable of infinite transmutations, does not admit of creation or destruction,* is the chief corner-stone of modern chemistry. Lavoisier, the great French chemist, did much to establish this important law by his classical experiments on the formation of oxide of mercury, by heating mercury in the presence of air. In these experiments the mercury was placed in a retort which communicated directly by a bent limb with a bell jar of air standing over mercury—(Fig. 1)—so that the only air affected was that in the retort and bell jar. As the mercury was heated scales of the red oxide appeared on the surface, and together with this appearance mercury rose in the bell jar, proving that a portion of the air had been removed. The volume of air so removed was carefully measured. The retort was then broken and the scales of oxide of mercury collected and weighed. These were then heated to a higher temperature, mercury was produced, and a quantity of gas driven off. This was proved to be

oxygen gas, and was found to be of exactly the same volume as that which had disappeared from the air in the previous experiment. The loss in weight due to the heating of the oxide was, moreover, found to be exactly the weight of the oxygen collected. Thus proving, that although the mercury increased in weight on heating, due to its conversion into oxide, the gain was exactly counterbalanced by the loss of oxygen in the air.

A candle in burning loses weight, but in doing so pro-

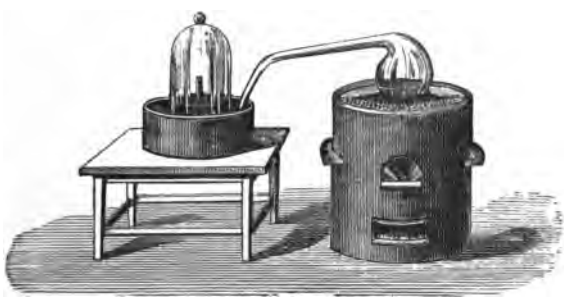


Fig. 1.

duces carbonic acid gas and water vapour. By a simple experiment the gases so formed may be collected and weighed, and it is found that these weigh more than the loss in weight of the candle. If, however, the volume of oxygen is measured which is used up during the burning, the weight of this gas is found to correspond with the excess of the weight of the products of combustion over the loss in weight of the candle.

Similarly, if gun cotton is burnt in an enclosed volume of air though important chemical changes have taken place, the vessel and its contents will weigh the same at the end as at the beginning of the experiment.

No law is placed upon a surer foundation than that of the indestructibility of matter, and if our planet with its atmosphere could be weighed from day to day, although an infinite variety of changes in matter must necessarily have taken place, no difference in weight could be detected unless some foreign body had fallen on it during the interval.

3. **Elements, Compounds, and Mixtures.**—At the present time there are about seventy substances *which have never been resolved into simpler bodies;* these are therefore termed *elementary substances or elements.* Thus iron is regarded as an element, because by no process of separation at present known can it be resolved into bodies having different properties. Starting from this as a fundamental substance, a large variety of bodies can be obtained by union with other substances, but from these iron can again be obtained by appropriate methods. It is possible, however, that with improved methods of separation, certain bodies now regarded as elements may be resolved into simpler ones, in which case they will lose their claim to be called elements. Thus caustic potash was for a long time regarded as an element until Sir H. Davy, by means of electrical separation, obtained the metal potassium from it. It is now known to be a chemical compound of three elements—potassium, hydrogen, and oxygen.

A chemical compound can be separated into substances having different properties from itself. This loss of the properties of its constituent elements is a characteristic feature of compounds. Common salt has become a necessity as an article of diet, yet it is composed entirely of a metal of a most active nature, which splits up water with explosive violence, and a poisonous gas of irritating odour. If the average amount of salt taken per day were resolved

into its elements, sodium and chlorine, and taken as such, the results would be fatal. Carbon in a finely divided state, as in overdone meat or bread, is continually taken into the body without evil results, and without oxygen life even for five minutes would be impossible; yet when carbon and oxygen are united together to form carbon monoxide, a gas of the most poisonous nature is produced.

This loss of individual properties only obtains, however, on chemical union of the constituents, and by this means it is possible to distinguish between compounds and mixtures of bodies. The elements iron and sulphur unite in definite proportions to form a chemical compound—sulphide of iron. The difference between an intimate mixture of these elements in proper proportions, and the result obtained on heating the mixture, illustrates clearly the difference between the terms mixture and compound.

On looking at the mixture under the microscope the particles of sulphur are discernible from those of iron. A magnet attracts the iron and leaves the sulphur. Carbon bisulphide dissolves the sulphur and leaves the iron, while dilute sulphuric acid dissolves the iron and leaves the sulphur. Sulphur being lighter than iron can be washed away with a gentle stream of water, leaving the heavier particles of iron. Thus the elements in the mixture retain their individual properties and can be readily separated. Now heat the mixture, it begins to glow, considerable heat being given out, due to the energy of chemical union. If the black mass formed is now examined under the microscope no particles of iron or sulphur can be seen. The magnet has practically no attraction for it, water cannot separate the elements, carbon bisulphide has no effect upon it. The properties of the elements have disappeared,

and a body having entirely new properties has been produced, from which the individual elements can only be obtained by difficult chemical processes, by the application of energy in some form equivalent to the energy of chemical union, as evidenced by the evolution of heat in its formation.

Gunpowder is also a good example of a mixture. It consists of a chemical compound nitre, and two elements —carbon and sulphur. Here separation is easy, due to the retention of their individual properties by the constituents. Nitre is soluble in water, the other bodies are insoluble; after separating the nitre by shaking up with water, the resulting mixture of carbon and sulphur is treated with carbon bisulphide, which dissolves the sulphur and leaves the carbon. The nitre can be obtained from the aqueous solution, and the sulphur from the carbon bisulphide solution, by evaporation, and thus the mixture resolves itself into its components.

4. **Atoms and Molecules.**—Two views have been held as to the constitution of matter—

(1) That it is indefinitely divisible.

(2) That there is a limit to such divisibility, that limit being reached when we arrive at small particles termed atoms. Dalton held the latter view, and as a result of his investigations the atomic theory took a definite shape.

Atoms are the indivisible constituents of molecules. They are the smallest particles of elements that take part in a chemical reaction, and are for the greater part incapable of existence in the free state, being generally found in combination with other atoms either of the same kind or of different kinds.

Hydrogen being the lightest element known is taken as the standard, and the other elements are represented in terms of this one. Thus the statement that the atomic

weight of oxygen is 16, means that the atom of oxygen is 16 times heavier than the atom of hydrogen, whatever that may be.

A molecule is the smallest particle of an element or compound that is capable of existence in a free state.

No matter how finely divided a compound may be, the smallest particle retains the properties of the substance until the molecule is reached: if division is carried further these properties are lost, and the compound is resolved into its constituents.

Assuming the molecular theory of matter, we conclude that, provided we had magnifying powers for our microscopes infinitely greater than those at present in use, we should find that a drop of water under such a microscope would consist of innumerable little particles—the molecules of water—and that these again would be built up of atoms of oxygen and hydrogen.

If a cubic inch of water is raised to the boiling point it produces about 1600 inches of steam at that temperature. This steam can then be raised to a higher temperature, so that we may have 10,000 cubic inches of steam produced from this small quantity of water. Although the water in the form of steam is now distributed over an area 10,000 times as great as at the commencement of the experiment, we find that, if we examine a small quantity of the steam, it retains all the chemical properties of water, and we are still dealing with exactly the same kind of particles we had to start with.

If, however, we pass some of the steam over a coil of white-hot platinum it is broken up into its constituent elements—hydrogen and oxygen; if we rapidly cool down these products below the temperature at which they unite

to form water, we can obtain a mixture of these gases, having properties widely different from the steam from which they were derived. Thus the point at which the separation goes beyond the molecule is marked by a change in the nature of the material.

Many attempts have been made to calculate the dimensions of molecules, and the results accord fairly well. To give an idea of the size of a molecule of water it is stated that if we conceive a sphere of water as large as a pea to be magnified to the size of the earth, each molecule being magnified to the same extent, the magnified structure would be coarser-grained than a heap of small lead shot, but less coarse-grained than a heap of cricket balls.

The number of molecules contained in a cubic inch of gas at 0°C. and 760 mm. pressure has been calculated to be about one hundred thousand million million millions. Now, a cubic inch of hydrogen under these conditions weighs ·0014 of a gram; dividing this by 10^{23} the weight of a molecule of hydrogen is obtained — viz., ·00000000000000000000000014 of a gram.

These molecules of gases are always in rapid motion. Thus the mean velocity of hydrogen molecules at 0°C. and 760 mm. pressure has been calculated to be about 6000 feet per second.

5. **Avogadro's Law. Molecular Weights.**—Avogadro's law states that *equal volumes of gases under the same conditions of temperature and pressure contain the same number of molecules.* In other words, the volumes occupied by gaseous molecules under like conditions are equal. Therefore, if we weigh equal volumes of two gases under the same conditions, the relations of these weights represent the relation between the weights of the molecules of the gases.

It is evident from this law that if we can obtain the weight

of our standard molecule hydrogen, there is no difficulty in determining the molecular weight of any gas or vapour. The determination of the molecular weight of hydrogen becomes, therefore, an all-important matter. Hydrochloric acid gas is a compound of hydrogen and chlorine united in the proportion of 1 part by weight of hydrogen to 35·4 parts of chlorine, and there is very strong evidence that this compound contains only 1 atom of each of these elements. It is found that when a compound contains more than 1 atom of hydrogen it is possible to replace this element by others in different stages. Thus in water the hydrogen can be replaced in 2 stages, and we conclude there are 2 atoms of hydrogen in the molecule of water. In hydrochloric acid, however, it is found impossible to replace part of the hydrogen; it must either be all or none. Sodium, for example, replaces it to form sodium chloride or common salt, but no intermediate compound can be formed between hydrochloric acid and sodium chloride. Similarly there is every reason to conclude that the molecule contains only 1 atom of chlorine. If we therefore assume that the molecule of hydrochloric acid contains only 1 atom of hydrogen and 1 of chlorine, its molecular weight — that is, the sum of the atomic weights—must be 36·4. In other words, the molecule of hydrochloric acid is 36·4 times heavier than an atom of hydrogen. The next step is to determine how much heavier a certain volume of hydrochloric acid gas is than an equal volume of hydrogen under the same conditions. For this purpose a flask is rendered vacuous and weighed, then filled with hydrochloric acid gas and weighed again. The difference in these weights gives the weight of the flask full of hydrochloric acid. In the same way the weight of the flask full of hydrogen is determined.

It is found that the hydrochloric acid weighs 18·2 times

as much as the same volume of hydrogen. Now it is evident from Avogadro's law that we are dealing with the same number of molecules in either case, and since the molecular weight of hydrochloric acid is assumed to be 36·4, the molecular weight of hydrogen must be 2.

From another standpoint, assuming the composition of hydrochloric acid, it can be proved that the molecule of hydrogen contains 2 atoms.

Five volumes of hydrogen unite in the presence of bright sunlight with 5 volumes of chlorine to form 10 volumes of hydrochloric acid. We therefore know that 5 molecules of hydrogen unite with 5 molecules of chlorine to form 10 molecules of hydrochloric acid. But each molecule of hydrochloric acid contains 1 atom of hydrogen, therefore there must be 10 atoms of hydrogen in 5 molecules, and therefore each molecule of hydrogen contains 2 atoms.

Having determined the molecular weight of hydrogen the determination of other gases becomes a simple matter; carbonic acid, for example, is 22 times heavier volume for volume than hydrogen, the molecular weight is therefore 44.

6. **Chemical Symbols.**—The name given to a chemical element generally refers to its most characteristic property. Thus the name hydrogen signifies that this element produces water. Oxygen was so named under the false impression that it was a necessary constituent of all acids; chlorine indicates the yellowish-green colour of this gas, and bromine was so named because of its offensive smell. In some cases, however, it is more difficult to trace the origin of the name.

The first letter of the common name, or its Latin equivalent, is generally used as the symbol, and where more than one element commences with the same letter, the one first discovered, or the most common one, takes the first letter, and

the others are indicated by a second letter in the name in addition to the initial one, thus several elements commence with C, such as Carbon (C), Chlorine (Cl), Cobalt (Co), Calcium (Ca), &c.

Each symbol represents an atom of the element in question, and therefore a definite mass. Thus the symbol C means 1 atom of carbon, or 12 parts by weight of this element, the atom of hydrogen being taken as unity.

In the following list some of the more important elements are given with symbols and atomic weights, which are sufficiently accurate for general use.

Name of Element.	Symbol.	Atomic Weight (H = 1).
Aluminium	Al	27·3
Barium	Ba	137
Bromine	Br	80
Calcium	Ca	40
Carbon	C	12
Chlorine	Cl	35·5
Copper	Cu (Cuprum)	63·5
Fluorine	F	19
Gold	Au (Aurum)	197
Hydrogen	H	1
Iodine	I	127
Iron	Fe (Ferrum)	56
Lead	Pb (Plumbum)	207
Magnesium	Mg	24
Manganese	Mn	55
Mercury	Hg (Hydrargyrum)	200
Nitrogen	N	14
Oxygen	O	16
Phosphorus	P	31
Potassium	K (Kalium)	39·1
Silver	Ag (Argentum)	108
Silicon	Si	28
Sodium	Na (Natrium)	23
Sulphur	S	32
Zinc	Zn	65

7. **Formulæ. Equations.**—Compounds are represented by combinations of symbols called formulæ, which indicate the number of atoms of the constituents present in a molecule of the substance. Where more than one atom of a particular element is present in a compound, a small number is written after the symbol for that element.

Thus the formula for carbonic acid is CO_2, which indicates that the molecule of this compound consists of 1 atom of carbon and 2 atoms of oxygen, and since the atomic weight of carbon is 12, and that of oxygen 16, we know that the molecule of carbonic acid is 44 times heavier than an atom of hydrogen, and that this is made up of 12 parts by weight of carbon, and 32 parts by weight of oxygen. Similarly H_2O is the formula for water, and denotes that a molecule of this compound consists of 2 atoms of hydrogen united with 1 atom of oxygen, and that in 18 parts by weight of this substance there are 2 parts by weight of hydrogen and 16 parts by weight of oxygen.

When different substances act upon each other and produce new combinations, and we know the chemical nature and proportions of the initial and final bodies, the changes may be represented by a chemical equation. The sign + placed between two bodies represents the addition of one substance to another, or the production together of bodies so connected. The sign of equality = has its true meaning only with regard to the masses of the interacting substances. Thus, in accordance with the law of the indestructibility of matter, the mass of the initial substances must be equal to the mass of the products of the reaction.

Apart from this, the sign of equality is equivalent to "produces" and shows the nature of the chemical change.

When carbon burns in oxygen, carbonic acid gas is produced, the equation representing the change being

$$C + O_2 = CO_2.$$

This not only shows the nature of the change, but also indicates the mass reaction, for since 1 atom of carbon (12) unites with a molecule of oxygen (32) to form a molecule of carbonic acid (44), and the reaction as a whole consists of multitudes of these atomic reactions, therefore 12 parts by weight of carbon unite with 32 parts by weight of oxygen, to form 44 parts by weight of carbonic acid, no matter whether parts refer to ounces, pounds, or tons. When carbonate of lime, the molecule of which consists of 1 atom of calcium, 1 of carbon, and 3 of oxygen, is heated to a high temperature, carbonic acid is given off, and quicklime, the molecule of which consists of 1 atom of calcium and 1 of oxygen, remains. The equation representing the change is—

Carbonate of Lime.		Quicklime.		Carbonic Acid.
$CaCO_3$	=	CaO	+	CO_2.

This indicates that a molecule of carbonate of lime produces a molecule of quicklime and a molecule of carbonic acid. The molecular weight of $CaCO_3$ is 100, because $Ca = 40$, $C = 12$, and $O_3 = 48$ (3×16). In the same way the molecular weight of CaO is 56, and that of CO_2 is 44. Therefore 100 parts by weight of carbonate of lime would yield, on heating, 56 parts by weight of quicklime, and 44 parts by weight of carbonic acid.

8. **Acids, Bases, and Salts.**—It is almost impossible to give rigid definitions, marking clearly the boundaries between these three classes of substances, although in

practice no difficulty is found in distinguishing between them.

For general purposes we may define an acid to be *a chemical compound with a sour taste, with the power of turning blue litmus red, and containing hydrogen, one or more atoms of which can readily be replaced by a metal.*

Bases, on the other hand, *have the power of neutralising acids.* They are generally compounds of metals with oxygen (oxides), or of metals with hydrogen and oxygen (hydroxides). In many cases these bases are soluble in water, and have alkaline properties, turning red litmus blue, or turning crimson a colourless solution of phenol phthalein.

When an acid is thus acted upon by a base a salt is produced, part or all of the hydrogen of the acid being replaced by a metal. If all the replaceable hydrogen is thus exchanged, the compound so formed is termed a normal salt; if part only, it is called an acid salt. Thus, if an alkaline base, such as caustic soda (NaOH), is treated with hydrochloric acid (HCl), a neutral salt, sodium chloride (NaCl), is produced, thus—

Caustic Soda.		Hydrochloric Acid.		Sodium Chloride.		Water.
NaOH	+	HCl	=	NaCl	+	H_2O.

Since hydrochloric acid has only 1 atom of hydrogen, it is evident that no acid salt can be formed; but if we treat sulphuric acid (H_2SO_4) with caustic soda, we may get an acid or normal salt depending upon the amount of caustic soda added.

Sulphuric Acid.		Caustic Soda.		Acid Sodium Sulphate.		Water.
H_2SO_4	+	NaOH	=	$NaHSO_4$	+	H_2O

Sulphuric Acid.		Caustic Soda.		Normal Sodium Sulphate.		Water.
H_2SO_4	+	$2NaOH$	=	Na_2SO_4	+	$2H_2O$

A neutral body is one which has neither acid nor alkaline properties.

9. **Weights and Measures.**—The English system of weights and measures is in every way inferior to the French or Metric system. The latter has the advantage of being a decimal system, and moreover there is a definite and easy connection between measurements of length, volume, and weight. The metre is taken as the standard of length, and is 39·37 inches. It was thought that this represented exactly a ten-millionth part of the arc from the equator to the north pole, but more recent observations have shown that this is not the exact fraction of that distance; the metre is therefore an arbitrary standard.

From the metre, by using Latin prefixes, sub-divisions are obtained, and multiples by using Greek prefixes, thus—

1 metre	=	10 decimetres (dm.).
	=	100 centimetres (cm.).
	=	1000 millimetres (mm.).

Similarly a decametre, hectometre, and kilometre represent 10, 100, and 1000 metres respectively.

The unit of capacity is taken as a cubic decimetre or litre, and since

1 decimetre	=	10 centimetres
1 litre	=	1000 cubic centimetres.

A cubic centimetre of pure water at 4°C. is taken as the unit of weight, and is called a gram; the prefixes are used as with the metre, therefore a milligram is one-thousandth part of a gram, and a kilogram 1000 grams.

The following shows the connection between some of the measurements on the French and English systems:—

1 metre	=	39·37 inches.	
760 millimetres	=	29·92 „	
1 litre	=	1·76 pints	= 61 cubic inches.
1 gram	=	15·43 grains.	
1 kilogram	=	2½ pounds.	

In order to compare the volumes of bodies it is necessary to refer them to some standard temperature and pressure.

It is found convenient to take the standard temperature as 0° on the Centigrade scale (0° C.), and the standard pressure as represented by a mercurial column of 760 millimetres.

At a pressure of 760 mm. the freezing point of water on the Centigrade scale is 0°C. and the boiling point 100°C.; whereas, on the Fahrenheit scale, the freezing point is 32°F. and the boiling point 212°F.

CHAPTER II.

THE ATMOSPHERE.

10. **Pressure.**—The atmosphere is the name given to the gaseous envelope surrounding our planet. From the earliest times it was observed that this invisible material had certain powers of resistance at rest: the tree torn from the soil, and the ship forced upon the rocks, gave evidence of its irresistible power when in rapid motion.

No good means of measuring the pressure of the atmosphere was discovered until the seventeenth century, when, as the result of the well-known researches of Torricelli and Pascal, the barometer was introduced and has remained to the present day the most trustworthy agent for this purpose.

Liquids have the power of transmitting pressure without loss in all directions. Thus, if we take a large vessel with a small neck, say 1 square inch in section, and fill the vessel with water, then apply a pressure of 2 pounds to the water in the neck, this pressure is transmitted in all directions, and on each square inch of surface on the inside of the vessel there is a pressure of 2 pounds, in addition to the weight of water at that particular point, no matter what the shape of the vessel may be. This principle has been applied with the greatest success in the various form of hydraulic presses.

By assuming this transmission of force by liquids in all directions, the principle of the barometer can be explained.

Take a piece of glass tubing about 36 inches long, closed at one end, and fill it with dry mercury: close the end to prevent any escape of liquid, and then invert it in a bowl of mercury (Fig. 2).

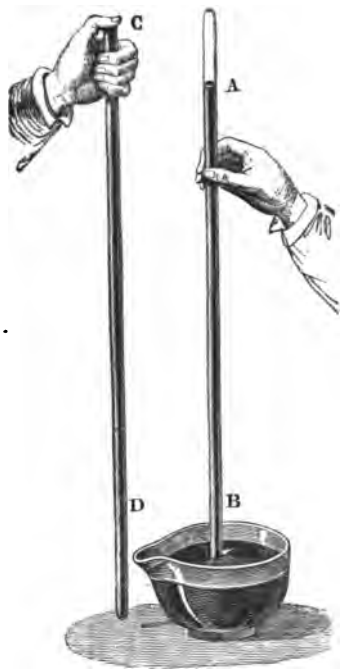


Fig. 2.

The mercury at the closed end of the tube falls about 6 inches, and after oscillation has ceased, measure the distance between the surface of mercury in the tube and that in the bowl. If the pressure is normal this will be found to be about 30 inches. It is evident that there can be no air between the surface of the mercury and the closed end of the tube, therefore there can be no pressure on the surface; atmospheric pressure being produced by innumerable tappings of the particles of gases in the air on the surface affected.

Imagine the tubing to be 1 square inch in section, then there will be only 1 square inch of surface in the bowl unacted upon directly by the pressure of the atmosphere, and therefore, the pressure, being transmitted in all directions, will sustain in the tube a column of mercury exactly equal to the pressure of the atmosphere on a

square inch of the surface of the liquid in the bowl. We therefore say the pressure of the atmosphere is about 15 lbs. to the square inch, because this represents the weight of 30 cubic inches of mercury. This explanation is confirmed by the rise of mercury in the barometer on taking it down into a coal mine, and its fall on going up a mountain.

Experiments illustrating the principle of the barometer can readily be performed. A wineglass full of water, the mouth being covered with a piece of paper, can be inverted, the pressure of the atmosphere sustaining the column of water. A long burette full of water can be inverted, provided the rim of the open end is covered with vaseline to prevent the water dripping. If held quite vertically, and the tap is turned to let in air, water flows out, but if only a small quantity of air is admitted the flow is arrested, as the rarified air exerts less pressure than the air at the open end, the difference being represented by the column of water sustained.

11. **Extent of Atmosphere.**—From experiments made on the duration of twilight, it appears that the column of air surrounding the earth reaches to a distance of about 50 miles. It is probable, however, that in a very attenuated form, it goes far beyond this limit. As the result of investigations made with regard to the diminution of pressure of the atmosphere at different heights, it has been calculated that at a height of 7 miles from the surface of the earth the barometer would stand at about 190 mm. (the pressure at the sea-level being 760 mm.), at a height of 17½ miles it would register 24 mm., and at a distance of 45 miles the mercury in the tube would probably not be more than 2 mm. above the mercury in the bowl.

The total pressure on the body of a man must be several tons, but the external and internal pressures are so balanced that no inconvenience is felt. The unpleasant sensations experienced on going up in a balloon, or in a rapid descent into a coal mine, are largely due to the alterations in external pressure before a corresponding change has taken place in the internal pressure.

12. **Chemical Composition.**—At the latter part of the seventeenth century, valuable work was done by Hooke and Mayow on the nature of the gases composing our atmosphere. It was proved that there were two substances present, one playing an important part in burning and respiration, the other having no power of aiding in these processes. Then came a retrograde movement; that odd theory of combustion, called the phlogiston theory, was embraced by the leading scientists of Europe, and the glorious advances of Hooke and Mayow were forgotten. In 1774 Joseph Priestley obtained oxygen by concentrating the rays of the sun on some red oxide of mercury, and it was soon proved that this was the essential element in the atmosphere concerned in the processes of combustion and respiration. By the careful work of Cavendish the proportion of oxygen to nitrogen was accurately determined. Black proved the existence of carbonic acid gas in the atmosphere, and showed that this gas existed in large quantities in expired air. He also proved that the same gas could be obtained by heating carbonate of lime which splits up into quicklime and carbonic acid.

In addition to these gases the air contains variable quantities of aqueous vapour, ozone, nitric acid, and ammonia.

Composition of pure air by volume—

Nitrogen	.	79·00 per cent.
Oxygen	.	20·96 „
Carbonic Acid	.	·04 „
Aqueous Vapour	.	Variable.
Ozone, Nitric Acid, Ammonia	.	Traces.

13. **Composition by Weight.**—This determination was made with great accuracy by two distinguished French chemists. The method used depends upon the fact that red-hot copper will unite with oxygen to form the black oxide of copper (CuO)

$$Cu + O = CuO,$$

the nitrogen being left untouched. The apparatus consisted of a large round-bottomed flask, which was connected with a piece of strong glass tubing, filled with copper turnings. To this were attached U tubes filled with substances which would remove such bodies as carbonic acid and water vapour from the air. The large flask and the tube containing the copper, which were both fitted with stop-cocks, were rendered vacuous by means of an air-pump, and weighed separately. The apparatus was then fitted up, the tube, filled with copper, being placed in a furnace. When this portion of the apparatus was red-hot, the stop-cocks were turned slightly, so that a gentle current of air was drawn through the U tubes. The oxygen was seized upon by the copper, and the nitrogen passed on into the large flask. The apparatus was then cooled down, and the parts weighed again. The increase in weight of the flask gave the

amount of nitrogen, and the increase in the tube the amount of oxygen accompanying it. The results of many experiments by this method proved that to every 77 parts by weight of nitrogen there were 23 parts by weight of oxygen.

Thus the composition by weight of dry air is—

Oxygen = 23 per cent.
Nitrogen = 77 „

The composition of air by volume may be determined much more readily, and from this the composition by weight can be calculated. The results so obtained confirm in every way the accuracy of the above determination.

14. **Composition by Volume.**—Joseph Priestley determined the relation between the volumes of oxygen and nitrogen in the atmosphere, using for this purpose nitric oxide. Nitric oxide is insoluble in water, but in contact with air it unites with the oxygen, forming higher oxides of nitrogen of a reddish brown colour, which are soluble. Thus, if a measured sample of air in a tube stands over water, and nitric oxide is let in until no more fumes are formed, the water rises in the tube, showing the amount of oxygen originally present.

The method adopted by Cavendish, with such excellent results, consisted in firing a known volume of air with hydrogen in a eudiometer tube. This method is the one in present use.

Before making an accurate analysis it is necessary to determine roughly the proportion of oxygen to nitrogen. To do this, take a piece of glass tubing open at one end, introduce some small pieces of phosphorus, and close the tube with a tightly-fitting cork. On warming the

tube the phosphorus takes fire, uniting with the oxygen to form phosphorus pentoxide (P_2O_5), a white powder which is very soluble in water. When the phosphorus is burning the tube should be well shaken to bring the oxygen present into contact with the phosphorus, to ensure the union of all the oxygen. When the burning has ceased, the corked end of the tube is placed under water, and the cork removed, the white powder dissolves, and water rises in the tube. If the experiment is successful, the water will stand one-fifth of the way up the tube, showing that air contains about 20 per cent. of oxygen by volume. On testing the remaining gas it is found to be nitrogen. Therefore, in 5 volumes of air, there are about 4 volumes of nitrogen, and 1 of oxygen.

When hydrogen unites with oxygen to form water (Chap. VI.), the union takes place in the proportion of 2 volumes of the former to 1 of the latter, and as 2500 volumes of the mixed gases would only produce about 1 volume of water at ordinary temperatures, the amount produced in an analysis may be disregarded. Having made a preliminary determination of the proportion of oxygen to nitrogen, and knowing the relation in which hydrogen and oxygen unite to form water, we can proceed to an accurate analysis.

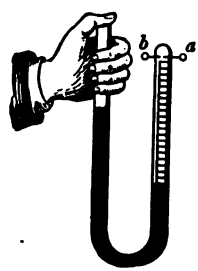


Fig. 3.

For this purpose a sample of air from which aqueous vapour and carbonic acid have been removed is placed in a eudiometer tube (Fig. 3) over mercury, the volume is carefully determined, and then hydrogen is introduced in sufficient quantity to

fire the whole of the oxygen present. The necessary volume can be calculated from the preliminary experiment and a knowledge of the proportion in which hydrogen and oxygen unite. The total volume having been read off, an electric spark is passed across the space between the platinum wires (*a*, *b*) in the tube. An explosion takes place, the whole of the oxygen present in the sample of air uniting with the hydrogen to form water. A large quantity of gas having disappeared, the mercury rises in one limb of the tube, and mercury is poured into the other limb to the same level, so that the pressures may be the same. In all experiments on the measurement of gases the temperature and pressure must be taken into account, otherwise it is impossible to get comparable results.

From the final volume we see how much gas has disappeared, and since one-third of this must represent the oxygen, the amount present in the volume of air taken can be calculated.

In an actual experiment, the volume of air taken was 100 cc., and to this was added 50 cc. of hydrogen. After firing, the residual volume was 87 cc., showing a diminution of 63 cc. (150 – 87); therefore in 100 cc. of air there are 21 cc. ($\frac{63}{3}$) of oxygen and 79 cc. of nitrogen.

The relation by volume is therefore—

Oxygen	. .	21 per cent.
Nitrogen	. .	79 „

Oxygen being heavier, volume for volume, than nitrogen, accounts for the larger percentage of oxygen (23) by weight.

15. **The functions of Oxygen and Nitrogen.**—Life on

this planet without oxygen would be impossible even for a short space of time, such an important part does it play in all processes of life and health. Passing by diffusion through the air-cells of the lungs into the small blood-vessels, it is carried by the blood stream to every part of the body. Here, by its oxidising action, complex bodies are broken down, resulting in the evolution of heat, and thus maintaining the warmth of the body. It is the primary agent in all processes of burning and lighting: the avidity with which it enters into combination with combustible material leading to the production of heat and light. It is thus the essential element in producing internal and external warmth.

Oxygen is also the arch-enemy of all forms of disease. By its action the disease-producing germ loses its sting and becomes powerless: poisonous organic matter is oxidised and broken up into harmless combinations, and malodorous bodies, under its benign influence, lose their offensive smell. The herding together of masses of people in small dwellings, in overcrowded cities, and the various devices by which the free circulation of air is prevented, are the most powerful agents in the spread of disease. The purifying action of oxygen is well shown in the analysis of river waters at different points. In passing through the town, river water becomes polluted and absolutely undrinkable, by receiving sewage and other forms of impurity. The oxygen dissolved in the water at once goes to work upon the organic matter, and before the river has passed far beyond the borders of the town a very large percentage of the soluble matter has been destroyed by the agency of this gas, and the solid particles have been deposited.

Animals living under water are as dependent upon

oxygen for their life as land animals: this they obtain from the large quantity of this gas dissolved in the water. If water is boiled (in which process dissolved gases are driven off) and then cooled out of contact with the air, fish cannot live in it—death resulting from suffocation. In hard winters fish often die in lakes, when the surface is completely covered with ice, because the water cannot dissolve fresh supplies of oxygen; whereas, if air-holes are provided, they are not injuriously affected.

In vegetable life, oxygen also plays an important part. To carry on chemical processes in the plant which are essential to its life, the presence of free oxygen is absolutely necessary, except in the case of some microscopic organisms.

A plant placed in an atmosphere deprived of oxygen, though all other conditions for its life may be favourable, soon withers and dies. The useful action of oxygen is not confined to the atmosphere and water—it is necessary for the soil. Here certain minute vegetable organisms, which manufacture from dead organic matter suitable food for the plant, cannot carry on their important work without this gas. In the soil it also performs a useful function, in bringing about the conversion of insoluble into soluble material, thus rendering it available as food for the plant, which must be taken up in the form of solution.

Oxygen is the most interesting of all the elements; its companion in the atmosphere is one of the most uninteresting. Nitrogen is remarkable for its negative properties—it is made to unite with other bodies with considerable difficulty—and in many cases produces bodies of an unstable nature, differing in a marked degree from the stable bodies produced on oxidation. Its function—an all-important one—in the atmosphere is to act as a diluent

and prevent the too-violent action of oxygen. An animal placed in an atmosphere of pure oxygen after a period of violent fever, soon dies of exhaustion—the internal production of heat, and consequent wasting of the tissues, having gone on too rapidly. Similarly, in ordinary processes of combustion, the action in pure oxygen is much more violent than in air, and bodies, which will not burn in this medium, will burn with great brilliancy in oxygen. Nitrogen acts thus as a break upon the action of oxygen, keeping it in check.

The removal of nitrogen from the atmosphere would be as fatal as the removal of oxygen, and universal death would be accompanied by universal conflagration.

16. **Preparation and Properties of Oxygen.**—The preparation of oxygen by heating red oxide of mercury is historically interesting, being the means by which Joseph Priestley discovered the gas in 1774. The oxide, on heating, is resolved into mercury and oxygen.

$$HgO = Hg + O.$$

This method, however, is not used in practice.

It is generally obtained by heating potassium chlorate ($KClO_3$), which contains about 40 per cent. by weight of oxygen: the substance fuses, and if heated to a sufficiently high temperature, gives off the whole of its oxygen, leaving a white residue—potassium chloride (KCl .

$$2KClO_3 = 2KCl + 3O_2.$$

The gas is collected over water (Fig. 4), in which it is sparingly soluble. If black oxide of manganese (MnO_2) is mixed with the potassium chlorate, the whole of the oxygen comes off at a much lower temperature.

Various methods have been suggested for obtaining

oxygen from the atmosphere. The most successful of these depends upon the fact that barium oxide (BaO) will take up oxygen from the air at a certain temperature, and form barium peroxide (BaO_2).

$$BaO + O = BaO_2.$$

Whereas, if this peroxide is heated to a still higher temperature, it will give off oxygen, and the ordinary oxide is reproduced.

$$BaO_2 = BaO + O.$$

Thus, by alterations of temperature, and arranging the apparatus so that air may be swept over at one time, and

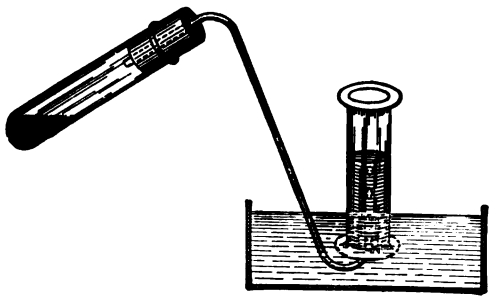


Fig. 4.

the oxygen passed into a reservoir at the other, large stores of the gas may be obtained.

Oxygen is a colourless, tasteless, odourless gas, 16 times heavier, volume for volume, than hydrogen. At ordinary temperatures, 100 volumes of water will dissolve about 3 volumes of oxygen.

With non-metals it unites to form acid-forming oxides, and with metals it forms basic oxides. In a finely divided state some elements, such as lead and phosphorus, will

unite with it at ordinary temperatures, others require a high temperature. It is the most widely distributed of all the elements. Oxygen is present in the rocks on the earth's surface to the extent of 46 per cent.; water contains 88 per cent., and the atmosphere 23 per cent., by weight, of this element.

17. **Combustion.**—The history of the views held with regard to combustion is interesting as illustrating the development of Chemistry. The great object of the alchemists was to find the philosopher's stone which should convert the baser metals into gold: then came the medical chemists, searching for the *elixir vitæ* which should confer on the individual immunity from all diseases to which flesh is heir. Robert Boyle, the greatest scientific reformer of his century, sounded the death-knell of the old views which regarded matter as composed of earth, air, fire, and water, or, according to the alchemists, of mercury, sulphur, and salt. He also denounced the search for the philosopher's stone as a dream which could never be realised, and exhorted his disciples to study Nature for her own sake.

The act of burning, about which so much centres, naturally claimed the attention of the modern chemists. The researches of Hooke and Mayow (p. 20) led to the belief that the air was a solvent, and that bodies dissolved in it as a solid dissolves in water; and just as water can only take up a certain quantity of a soluble substance, so, it was stated, a given volume of air can only take up a limited quantity of the combustible material. The analogy, however, was carried too far. At this early stage it was recognised that one constituent of the air was especially concerned in burning, and that this substance was present

in nitre (KNO_3) in large quantities. It was therefore called nitre-air or fire-air.

The phlogistic theory was then introduced by two German chemists, Beccher and Stahl. According to this theory combustible materials contained a fiery principle termed phlogiston, which escaped on burning. To explain why a candle went out in a limited supply of air, it was said that air could only take up a certain quantity of phlogiston, and the reason why one portion of the air supported combustion while the other had no such power, was explained by stating that one contained no phlogiston, and could therefore take up large quantities, whereas the other was already fully charged with this fiery principle. Thus oxygen, the great burning agent, was called air without phlogiston, or dephlogisticated air, and the negative body, nitrogen, was called phlogisticated air. The chemical balance now came into use and proved that certain bodies increased in weight on burning, though on the phlogistic theory they lost something; this was explained by the phlogistonists by the assertion that phlogiston was a principle of levity, and that when a body lost it, it increased in weight, and when it gained it, it lost in weight.

Notwithstanding the discovery of oxygen, and the proof of the composition of air and water, Priestley, Cavendish, and others remained firm supporters of this theory of burning, although their researches contained the essential elements for its complete overthrow, and it was left for Lavoisier, the great French chemist, to interpret the true bearing of their work. The mysterious fiery principle he proved to be simply the energy given out in the form of heat and light as the result of chemical union between

oxygen and the combustible body. The great problem, over which chemists had fought as eagerly as the alchemists had fought for the philosopher's stone, was solved, and on looking back we see how near Hooke and Mayow had come to the true solution of this important question.

The heat given out when 1 gram of carbon burns to form carbonic acid is sufficient to raise 8000 grams of water through 1°C., and when 1 gram of hydrogen burns to form water, the heat evolved would raise 34,000 grams of water through the same range of temperature.

18. **Preparation and Properties of Nitrogen.**—In determining the relative volumes of oxygen and nitrogen in the air (p. 22), oxygen is removed by burning phosphorus in it, and dissolving the oxide of phosphorus in water; the remaining gas is pure nitrogen and can be used to exhibit the properties of this element.

To prepare nitrogen on the large scale, a current of air is passed through a tube filled with small pieces of copper kept at a red heat; the oxygen unites with the copper to form black oxide of copper, and the nitrogen passes on, and may be collected over water. Nitrogen is a colourless, tasteless, odourless gas, and will not burn nor support combustion. It is 14 times heavier than hydrogen; united with hydrogen it forms an important gas, ammonia (NH_3), which has alkaline properties, and when neutralised with acids yields an important class of bodies—the ammonium salts. Thus, when treated with hydrochloric acid, ammonium chloride (NH_4Cl) is produced.

$$NH_3 + HCl = NH_4Cl.$$

Nitrogen also forms with hydrogen and oxygen an important compound, nitric acid (HNO_3). With oxygen

alone it forms several oxides, the most important of which are nitrous oxide or laughing gas (N_2O), and nitric oxide (NO).

19. **Carbonic Acid.**—By the definition of an acid hydrogen is a necessary constituent; this body therefore has no claim to be called an acid, it should be called carbon dioxide. With water it forms a very unstable body, the true carbonic acid (H_2CO_3), which has never been isolated.

$$CO_2 + H_2O = H_2CO_3.$$

It is present normally in the atmosphere to the extent of 4 parts per 10,000, and is of the greatest importance, being an essential constituent of the food of green plants, which, under the influence of sunlight, have the power of splitting up the gas, retaining the carbon, and giving back to the atmosphere an equal volume of oxygen. If the air contains carbonic acid much in excess of the normal quantity it is said to be vitiated; the chief cause of this vitiation is expired air, which contains about 4 per cent. of this gas.

Since the amount of carbonic acid present is taken as the standard of purity or impurity of a sample of air, good methods for determining the amount become a matter of great importance. Caustic potash (KOH), or caustic soda (NaOH), readily enters into combination with carbonic acid; therefore, if a current of air is passed through a solution, or through a U tube packed with solid particles, of either of these compounds, the whole of the carbonic acid is removed.

For this purpose an aspirator (*A*, Fig. 5) is filled with water, and a U tube packed with caustic soda (*B*, Fig. 5) is attached. On turning the tap of the aspirator the water

rushes out and an equal quantity of air passes through the tube. By filling the vessel with water several times a large known quantity of air is drawn through, and, by weighing the U tube before and afterwards, the increase in weight shows the amount of carbonic acid present in this quantity of air. In making this determination it is necessary to attach to the free end of *B* another tube containing some substance, such as calcium chloride, which will absorb the aqueous vapour from the air, because caustic soda also absorbs moisture.

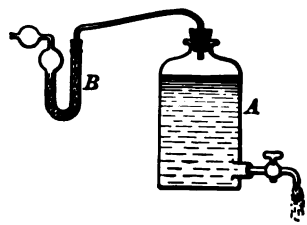


Fig. 5.

A more accurate method of determining the amount of carbonic acid is to take a solution of baryta of known strength, shake up with a known volume of air, and see how much baryta has been destroyed by its union with carbonic acid to form carbonate of barium, as described in Chapter V.

20. **Aqueous Vapour.** — Moisture is a necessary constituent of the atmosphere. The amount varies considerably from time to time, depending on changes of temperature, direction of the wind, and other circumstances. For a given temperature, air can only contain a certain quantity of moisture, it is then said to be charged, or to have reached its dew-point: the slightest fall of temperature then leads to the deposition of moisture in some form.

The maximum quantity that can be held at different temperatures has been determined, and if the temperature of a bright surface is suddenly lowered by the evaporation of ether, or other suitable means, and the temperature

noted at which a film of vapour is deposited on the bright surface, much information can be obtained with regard to the amount of moisture in the particular sample of air.

Instruments for measuring the amount of moisture in the air are called hygrometers. The most convenient one in general use is termed the wet and dry bulb hygrometer (Fig. 6). In this instrument two thermometers are fixed some little distance apart. The bulb of one is covered with muslin which is connected with a vessel containing water, so that the bulb is kept continually in a moist condition. The other thermometer is uncovered, and registers the normal temperature. If the air is already charged with moisture no evaporation will take place from the moist bulb, and the two thermometers will register the same temperature. If the air contains but little moisture evaporation will go on which will cool the covered bulb, and there will be a considerable difference between the readings of the two thermometers. From this the amount of moisture in the air can be calculated.

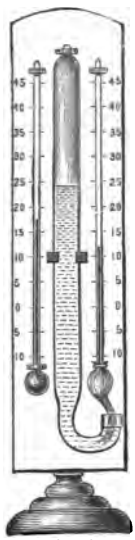


Fig. 6.

A more tedious method is to fill the U tube *B* (Fig. 5) with calcium chloride, and draw through, by means of the aspirator, a known quantity of air. The increase in weight of this tube gives the amount of moisture present.

21. **Ozone.**—When a silent electrical discharge takes place in a vessel containing oxygen a diminution in volume takes place, a portion of the gas being converted into ozone, which can be recognised by its characteristic smell. It

is a condensed form of oxygen, there being 3 atoms of this element in the molecule. The change which takes place when ordinary oxygen is converted into ozone is represented by the equation

$$3O_2 = 2O_3.$$

It can also be produced by allowing a moist stick of phosphorus to oxidise in a vessel of air.

In pure country air, traces of ozone can always be found, and in some districts there is much more than in others; it is absent, however, from the air of large towns.

It is much more active than ordinary oxygen, and rapidly oxidises organic matter. The health-giving properties of some places are attributed to the presence of this gas in comparatively large quantities. The presence of ozone may be recognised by its power of releasing iodine from potassium iodide. If this takes place in the presence of starch the iodine unites with it to give a blue colour, the depth of tint on exposure for a certain time depending upon the amount of ozone present. Papers are therefore dipped in solutions of potassium iodide and starch, and exposed to the air to be tested for a given time; the tint obtained is then compared with standard tints, and since these correspond to known quantities of ozone, for the same time of exposure, the required amount can be readily determined.

Oxides of nitrogen have the same power of releasing iodine from iodide of potassium, but in the case of ozone the paper is made alkaline, which is not the case if the colour is produced by the presence of oxides.

22. **Air a Mixture.**—The gases oxygen and nitrogen are present in the air as a mixture of these gases, not as a chemical compound. The reasons for this conclusion are:—

(1.) The analyses of air in different places show very slight differences in the proportion of oxygen to nitrogen, whereas in a chemical compound the relative proportions of the constituents are constant.

(2.) A mixture of 79 volumes of nitrogen and 21 volumes of oxygen behaves in every way as a sample of air, though no condensation of volume, evolution of heat, or other sign of chemical union can be observed.

(3.) The proportion of oxygen to nitrogen dissolved in water is greater than that in air. If it were a chemical compound it would dissolve as such.

(4.) The great ease with which oxygen will unite with other bodies points to its being in the free state rather than in combination.

CHAPTER III.

CARBON AND ITS COMPOUNDS.

23. **Carbon. Allotropic Modifications.**—The element carbon is found in three distinct forms—the diamond, graphite, and charcoal. Although widely different in their physical properties, they are identical in chemical composition. If pure samples of each modification be taken and raised to a sufficiently high temperature, in an atmosphere of oxygen, they burn with brilliancy to form carbonic acid gas, and if the same weight be taken in each case they will produce the same quantity of gas. Thus one gram of diamond, graphite, or charcoal will produce 3·6 grams of carbonic acid.

The diamond and graphite occur naturally as crystals of different shape, the former being so hard that it is used for cutting other hard bodies, the latter being so soft that it leaves an impression on paper, hence its commercial value as black-lead. The high dispersive power of the diamond for light makes it valuable, when properly cut, as an ornament; graphite has no such power. Charcoal has no crystalline structure, and is widely different in physical properties from the diamond or graphite. The weights of these varieties of carbon as compared with equal volumes of water are—diamond, 3·5; graphite, 2·2; and charcoal, 1·5.

The chemical identity of these bodies is not only proved by the common production of carbonic acid on burning in

oxygen, but also by the fact that one variety may be changed to another. Iron will, at certain temperatures, take up charcoal, and thus bring about most important changes in its physical properties, leading to the production of cast-iron or steel, depending upon the amount of carbon taken up. If cast-iron containing large quantities of carbon is melted and cooled slowly, scales of graphite separate out. The diamond, at the temperature of the voltaic arc, is converted into a variety of charcoal. Graphite may also be made to yield charcoal by proper treatment, and artificial diamonds have recently been produced from charcoal.

24. **Action of Charcoal on Obnoxious Gases.**—If a glass tube is partly filled with ammonia standing over mercury, and a piece of freshly-heated charcoal be introduced, the mercury rises rapidly, proving the absorption of the ammonia by the charcoal. Similar experiments performed with sulphuretted hydrogen, oxygen, and carbonic acid show that these bodies are also readily absorbed. The various kinds of charcoal have different powers in this respect, the variety produced by heating cocoa-nut shells out of contact with air giving the best results. The following table shows the volumes of different gases (measured at 0°C. and 760 mm.) absorbed by one cubic inch of cocoa-nut shell charcoal.

Oxygen . .	18	cubic inches.
Carbonic acid .	68	„
Sulphuretted hydrogen	100	„
Ammonia gas .	170	„

This power possessed by charcoal of absorbing gases in such enormous quantities makes it a powerful disinfecting agent, as, by its means, gaseous bodies injurious to health may be removed from the atmosphere. This action is

not simply one of absorption. Chemical changes go on within the charcoal by which the poisonous gases are entirely destroyed.

When organic bodies containing sulphur decompose, a poisonous gas of offensive odour, sulphuretted hydrogen (H_2S), is produced. The insufferable smell of rotten eggs is due to the presence of this gas. If a sample of sulphuretted hydrogen is burnt in a good supply of oxygen, the hydrogen unites with oxygen to form water, and the sulphur produces sulphur dioxide (SO_2), a gas with a characteristic suffocating smell, often used as a disinfectant.

$$2H_2S + 3O_2 = 2H_2O + 2SO_2.$$

This is exactly the reaction which goes on when this gas is taken up by charcoal. The charcoal, having been exposed to air, contains large quantities of oxygen, and this unites with the sulphuretted hydrogen, as it enters, to produce harmless products. To prove how energetically these gases unite, a small piece of freshly-heated charcoal may be placed in an atmosphere of sulphuretted hydrogen, and then thrown into a jar of oxygen; so violent is the chemical action that the charcoal bursts into flame.

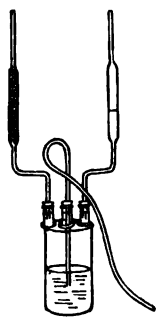


Fig. 7.

Foul smelling gases passing through charcoal lose all traces of their offensive odour. This can be easily demonstrated by the apparatus shown in Fig. 7. The three-necked bottle is partially filled with a strong solution of sulphuretted hydrogen in water. Through the central tube, dipping under the liquid, air may be blown, by which means quantities of gas may be sent into the exit tubes:

one of these is loosely packed with pieces of charcoal, the other is empty. On blowing through the apparatus the issuing gas coming from the tube containing charcoal has no smell, but that from the other has an intolerable odour. If the solution of sulphuretted hydrogen is very strong, the gas may be ignited at the mouth of the empty delivery tube, but not at the other.

That not a trace of sulphuretted hydrogen escapes from the tube packed with charcoal, may be proved by holding over it a piece of porous paper saturated with a solution of lead nitrate: such a piece of paper immediately becomes coloured on coming into contact with this gas, due to the formation of the black sulphide of lead, and is, therefore, a very delicate test for its presence. In this case no colouration takes place, but, on holding it over the mouth of the other tube, it at once indicates the presence of the gas.

This valuable property of charcoal is sometimes utilised in ventilating shafts of sewers, and other positions, in which it is necessary to destroy poisonous and offensive gases.

25. **Action of Charcoal on Liquids.**—A special form of charcoal is produced by heating bones out of contact with air; this is called animal charcoal, or bone-black, though it only contains about 10 per cent. of carbon, the chief constituent being phosphate of lime. Animal charcoal has the power of removing colouring matters: thus, if solutions of cochineal, logwood, or indigo be poured through a funnel packed with this substance, the colour will be partially or wholly removed. If the colour is difficult to destroy, some animal charcoal is put into a flask containing the liquid, it is then boiled for some time and filtered.

This property of charcoal is made use of in the refining of sugar, the dark colouring matter being entirely removed. The action of charcoal in purifying waters is a most important one. Being exceedingly porous, it removes particles held in suspension, and, in addition, acts chemically upon the dissolved organic matter; thus, water charged with organic impurities may be made drinkable by passing through thick beds of pure charcoal. The charcoal must be replenished from time to time, and that which has been used heated to a sufficiently high temperature to destroy any organic matters it contains, or the charcoal beds may become sources of impurity. Charcoal used for removing obnoxious gases should also be heated occasionally, or it may lose its power of purification.

26. **Compounds with Oxygen. Carbon dioxide.**—In questions of life and health, carbon dioxide, or, as it is more commonly termed, carbonic acid, receives much attention. Without its presence in the atmosphere, green plants cannot live, and it is of the utmost service, dissolved in water, in bringing into solution valuable substances in the soil used as plant food. On the other hand, every precaution must be taken to prevent an accumulation of this gas beyond a certain limit, otherwise the air becomes vitiated, and the continually breathing of such air predisposes to the most terrible forms of lung disease.

The composition of carbonic acid is easily proved. On burning a piece of charcoal in a known volume of oxygen, the whole of the gas disappears, and in its place is produced a colourless gas of exactly the same volume

(Fig. 8), having the characteristic properties of carbonic acid. The bulb *E* is filled with oxygen gas, and a piece of charcoal, placed in *D*, is ignited by passing an electric current through *CC*. It glows, uniting with oxygen to

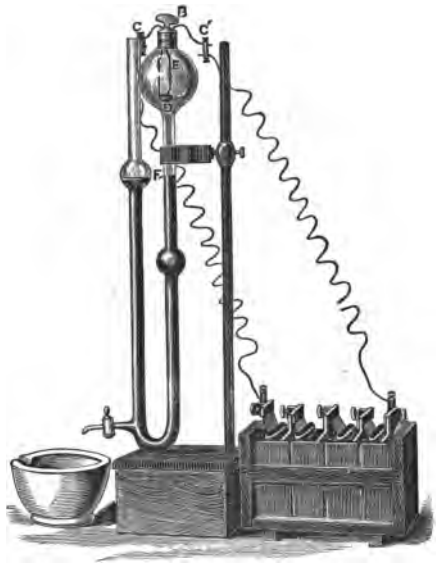


Fig. 8.

form carbonic acid. On cooling, the level of the mercury (*F*) is the same as at the commencement of the experiment. Thus we know that for every molecule of oxygen lost a molecule of carbonic acid is produced: in other words, carbonic acid contains its own volume of oxygen. This union is represented by the equation

$$C + O_2 = CO_2.$$

That this colourless gas contains carbon may be proved

in another way, by bringing it, under suitable conditions, into contact with an element which has a strong attraction for oxygen; the oxygen is then forcibly removed from its combination with carbon, and this element is deposited as a black mass. For this purpose a piece of potassium is heated in a strong piece of glass tubing, as shown in Fig. 9, dry carbonic acid is then passed over it, and the potassium unites with the oxygen to form a white

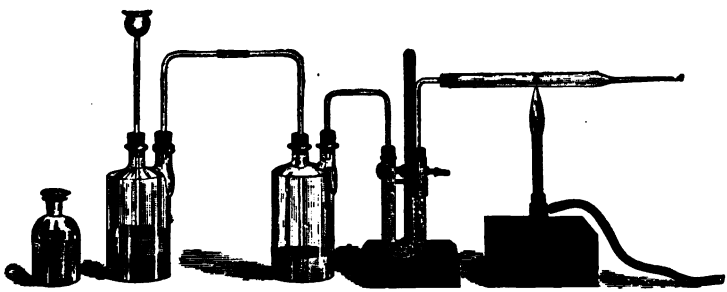


Fig. 9.

powder—potassium oxide (K_2O); the carbon being set free appears as a black deposit in the tube.

$$CO_2 + 2K_2 = 2K_2O + C.$$

The following method is the one generally adopted for preparing carbonic acid in large quantities. Hydrochloric acid is poured upon some pieces of marble, a variety of carbonate of lime ($CaCO_3$). The gas is given off in large quantities, and a soluble salt, calcium chloride ($CaCl_2$), and water are left in the generating flask.

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

Being very soluble in water it is inconvenient to collect car-

bonic acid over this medium, but being 1·5 times heavier than air it can be collected by downward displacement. The delivery tube is bent twice at right angles, and should be of such a length that it will reach to the bottom of the receiving vessel, which is placed mouth upwards. The heavier gas displaces the air, and when the vessel is full, if the mouth is covered over to prevent diffusion, it can be kept until required for experiment.

Carbonic acid is very easy of recognition. It is a colourless gas, extinguishes a taper, and gives a milky appearance when shaken up with a clear solution of lime water, which is prepared by dissolving quicklime in water, and filtering to remove any particles of undissolved lime. It can be poured from one vessel to another, like water, or may be siphoned off, baled out, or run off through a tap. These experiments can be seen more clearly by mixing the gas with a coloured substance, such as the reddish brown gas given off on heating nitrate of lead. One volume of water at 0° C. dissolves about two volumes of carbonic acid, and an acid solution is produced.

In the fermentation of sugar ($C_6H_{12}O_6$), large quantities of carbonic acid are evolved, alcohol (C_2H_6O) being left in solution.

$$C_6H_{12}O_6 = 2CO_2 + 2C_2H_6O.$$

In raising bread, yeast is mixed with the dough, and carries on these fermentative changes. Starch, being first converted into sugar, and then split up as in equation, the bubbles of gas given off separate the dough, particle from particle, and the bread is leavened.

27. **Storage of Energy in Green Plants.** — If some resh green leaves are placed in water, saturated with

carbonic acid, and then exposed to sunlight, bubbles of gas make their appearance on the leaves. In the apparatus shown in Fig. 10 these bubbles will collect in the small tube fixed in the mouth of the bottle; the tube is at first filled with water, which is displaced as the bubbles of gas rise up. When the tube is full it is removed, and on inserting a glowing splinter it bursts into flame, proving the gas to be oxygen.

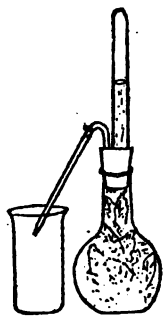


Fig. 10.

The green colouring matter, chlorophyll, of the plant, has the power, under the influence of sunlight, of splitting up the carbonic acid dissolved in the water, retaining the carbon and giving out the oxygen: this gas, being much less soluble in water than carbonic acid, rises into the tube.

It can be proved that the volume of oxygen given out equals in volume the amount of carbonic acid absorbed. Thus, if a glass tube is partly filled with carbonic acid over mercury, and at the top of the mercurial column some water is placed containing some low form of green plant life, and the apparatus is exposed to sunlight (the level of the mercury in the tube being accurately noted), no apparent change will go on, and the volume of gas in the tube will remain the same. If, however, after some hours the gas is tested, it will be found to be pure oxygen, the whole of the carbonic acid having disappeared, and having been replaced by an equal volume of oxygen; therefore, for each molecule of carbonic acid absorbed, a molecule of oxygen has been liberated. The equation representing the change is therefore

$$CO_2 = C + O_2.$$

This change is exactly the reverse of that which goes on when carbon burns in oxygen. The chlorophyll, in some way imperfectly understood at present, absorbs the radiant energy of the sun, and uses it in unburning the carbonic acid, storing the carbon in the wood of the plant which can again be used in giving out heat and light.

A pound of carbon on burning in oxygen gives out sufficient heat to raise 8000 pounds of water through 1° C., an amount of heat which, if converted into useful work, would raise about 5000 tons through 1 foot against gravity. Thus, in every pound of carbon fixed by the green plant, an amount of the sun's energy is stored, sufficient to raise a weight of 5000 tons through 1 foot. In burning coal in the present day we are making use of the energy of the sun which was stored up long ages ago in the forests of the carboniferous period.

28. **Compounds with Oxygen. Carbon Monoxide.**— When carbonic acid is passed through a tube containing red-hot charcoal, a gas is produced, having very different properties from the original. This gas is carbon monoxide (CO). The change which takes place is represented by the equation

$$CO_2 + C = 2CO.$$

This gas is present in large quantities in water-gas, which is manufactured by letting a jet of steam play upon red-hot charcoal, contained within a large cylinder, the gases produced being conducted into a reservoir. The chemical change is a simple one, the carbon uniting with the oxygen of the steam to form carbon monoxide, the hydrogen being liberated, thus—

$$C + H_2O = CO + H_2.$$

Carbon monoxide is a colourless gas of almost exactly the same density as air. It burns with a blue flame to form carbonic acid, and has no action upon lime water. A mixture of the oxides can thus be separated by passing them through caustic potash solution or lime water, the carbonic acid is absorbed, and a pure sample of carbon monoxide is obtained. It is very slightly soluble in water.

Carbon monoxide is very poisonous. It unites with the red colouring matter, hæmoglobin, of the blood (p. 58) to form a compound carboxyhæmoglobin. In the presence of this gas the blood loses its power as an oxygen carrier, as carboxyhæmoglobin is a much more stable combination than oxyhæmoglobin, the compound formed with oxygen. Carbon monoxide is produced in considerable quantities in slow combustion stoves. Great care should be taken in such cases to have sufficient ventilation; neglect of this precaution has often led to fatal results.

29. **Compounds with Hydrogen. Coal Gas.**—The gaseous products obtained on the destructive distillation of coal consists principally of hydrogen, and compounds of carbon and hydrogen—hydrocarbons—which are valuable for heating and lighting purposes.

An average sample of coal gas gave the following analysis:—

Hydrogen . . .	45·58
Marsh gas . . .	34·90
Carbon monoxide . .	6·64
Olefines . . .	6·46
Nitrogen . . .	2·46
Carbon dioxide . .	3·67
Sulphuretted hydrogen .	·29
	100·00

Of these, hydrogen, marsh gas, and carbon monoxide are valuable as heating agents, but are of little service for purposes of illumination. The olefines are valuable illuminants, and the nitrogen, carbon dioxide, and sulphuretted hydrogen are impurities.

When compounds of carbon and hydrogen—such as marsh gas and olefines—burn, carbonic acid and water are produced. As the hydrogen unites with oxygen more readily than the carbon, an insufficient supply of air leads to the separation of carbon in the form of smoke. With a very liberal supply of oxygen complete combustion takes place, which, however, affects the illuminating power, which is largely dependent on the existence in the flame of unburnt particles of carbon. The carbon and hydrogen should, therefore, be so balanced, that, with a good supply of air, particles of carbon should be set free in the flame to give it luminosity, but not in sufficient quantity to produce smoke. In the manufacture of charcoal from wood, sufficient air is admitted to burn the hydrogen —the carbon being left unburnt.

The result of replacing air by a current of oxygen in burning coal gas is to greatly increase the heating effect, but to reduce the luminous effect, of the flame. The oxyhydrogen flame produced by the union of oxygen and hydrogen has no direct value for illuminating purposes, but its great heating power is utilised to raise to incandescence a cylinder of lime, by which means a brilliant light is produced. In the same way with water-gas, it is necessary to introduce solid material into the flame if it is to be used for purposes of illumination.

30. **The constitution of Gases.**—In the gaseous state the constituent particles move about with varying velo-

cities depending upon the nature of the gas and the temperature; these molecules, by their incessant impacts against any surface, with which they come in contact, produce pressure.

If a gas, such as oxygen, is confined within a strong vessel, and the temperature is raised sufficiently, although the number of molecules must necessarily remain the same, the increase in the velocity of the particles leads to a greater number of impacts on the surface in a given time, and consequently an increase of pressure, which may result in the bursting of the vessel. If, on the other hand, an ordinary florence flask is connected with an air pump, and the air gradually removed from the vessel, the diminution of the number of particles leads to a reduction of the internal pressure, because the number of impacts on the surface becomes less and less. The pressure on the outside, however, remains the same—being equal to about 15 pounds on the square inch—and, sooner or later, the flask, being unable to stand the strain, will burst inwards. Similarly, if a very thin vessel is corked up when full of hot air, and then cooled, the diminution in the velocity of the particles may lead to such a difference between the external and internal pressure as to break the vessel.

A jar filled with carbonic acid exerts the same internal pressure as a similar one filled with hydrogen, under the same conditions of temperature and pressure. The number of molecules in each case we know from Avogadro's law to be the same, therefore the rate of movement of the heavier molecules must be less for the same temperature than the lighter ones.

The rapidity of movement of molecules of hydrogen,

nitrogen, and oxygen at 0° C. has been calculated to be

Hydrogen .	1844	metres per second
Nitrogen .	492	„ „
Oxygen .	461	„ „

the density of these gases being 1, 14, and 16 respectively.

The law, connecting together pressure with the weights of molecules and their velocities, states *that it is proportional to the sum of the masses of the molecules multiplied by the squares of their velocities.*

31. **Variations of the Volume of Gases with Changes of Temperature and Pressure.**—In comparing the volume of gases it is always necessary to refer them to some fixed temperature and pressure (0° C. and 760 mm.). If we measure the volume of a gas and note the height of the barometer, and the temperature, the volume at 0° C. and 760 mm. can easily be calculated. In speaking of the weight of a gas—*e.g.*, 1 litre of hydrogen = ·0896 grams—we mean the weight at standard temperature and pressure. The necessity for this reference to standards is evident when we study the laws which refer to the changes in volume of gases on alterations of temperature and pressure.

All perfect gases—that is, gases far removed from their point of condensation into liquids—expand to practically the same extent on heating through the same range of temperature. In this respect they behave very differently to solids and liquids, each of which has its own coefficient of expansion.

Gases expand $\frac{1}{273}$ *of their volume at* 0° C. *on raising the temperature through* 1° C.

Thus a cubic foot of gas at 0° C. becomes $\left(1 + \frac{10}{273}\right)$ feet at 10° C., and doubles its volume $\left(1 + \frac{273}{273}\right)$ at 273° C. On cooling gases the same law holds good for diminution of volume; therefore 1 cubic foot at 0° C. would become $\left(1 - \frac{50}{273}\right)$ of a foot at 50° C. below the freezing point (− 50° C.); and following this law no gas could exist as such at − 273° C. This temperature is, therefore, termed the absolute zero of temperature, and degrees on the centigrade scale can be converted into degrees on the absolute scale by adding 273, thus, − 10° C. becomes 263°, and 20° C. becomes 293°, on the absolute scale. It is very convenient in calculating the changes of volume in gases with temperature to use this scale, as the law of expansion then becomes *the volume of a gas varies with its absolute temperature.*

The law connecting change of volume with change of pressure is known as "Boyle's Law," which states that *the volume of a gas varies inversely with the pressure to which it is subjected.* Thus, if the pressure is doubled, the volume is halved; if the pressure is reduced to one-third, the volume is trebled. This can be proved by taking an apparatus similar to the eudiometer shown in Fig. 3, but with the open portion of the tube much longer. Air is placed in the closed portion, and the mercury made to stand at the same level on either side; the volume of the air is then read off —this will be at the ordinary atmospheric pressure. If mercury is now poured into the open limb until the level is 30 inches higher than that in the closed limb, the gas in the apparatus will be subjected to a pressure of two

atmospheres—the 30 inches of mercury representing the additional atmosphere. On reading the volume of the gas, it is found to be half its former value, showing that on doubling the pressure the volume is halved.

32. **Diffusion of Gases.** — If the stopper is removed from a bottle of liquid of offensive odour, such as carbon bisulphide, in a closed room, the vapour can very soon be recognised in every portion of it, giving evidence of the rapid diffusive power of this body, and also the universality of such diffusion. Diffusion will take place among gases of different densities even in opposition to gravity. Thus if a jar filled with a heavy gas is placed mouth upwards, and over this is placed a similar jar filled with a light gas, mouth downwards, it will be found, after a short time, that the gases will be equally distributed in the two jars.

Some gases will diffuse more quickly than others; thus if a jar is filled with carbonic acid and placed mouth upwards, and the rate of diffusion noted, and then the same jar is filled with hydrogen and held mouth downwards, it is found that the hydrogen diffuses five times as rapidly as the carbonic acid. The lighter the gas the more quickly will it diffuse, *the velocity of diffusion being inversely proportional to the square root of the density of the gas.*

The density of oxygen is 16, that of hydrogen being 1, and since the square root of 16 is 4, we should expect hydrogen to diffuse 4 times as quickly as oxygen, and we find by experiment that this is the exact relation between the rates of diffusion of these gases.

All gases will thus mix with each other by this process of diffusion, which is the most powerful agent in preventing the accumulation of heavy gases which would be disastrous in places with imperfect ventilation.

When liquids, such as mercury, chloroform, water, and ether are shaken up together in a vessel, they separate directly the movement ceases into four distinct layers in order of their specific gravities. If gases of different densities behaved in a similar way animal life on this planet would be impossible.

CHAPTER IV.

RESPIRATION.

33. **Function of Respiration.** — The chief object of respiration is to introduce oxygen into the blood stream; it is then carried to different parts of the body, and given up to the various tissues, where it is required to carry on important chemical changes, which result in an evolution of heat, and thus maintains the warmth of the body. Respiration also plays an important part in the removal of carbonic acid, the chief waste product in the chemical changes referred to. It is therefore necessary that continual supplies of oxygen should be presented to the blood when passing through vessels with sufficiently thin walls to admit of the passage of gases.

In the lower animals the aeration of the blood can take place over large portions of the body, but in the higher animals this process is confined almost exclusively to a definite area, which is specially modified for the purpose. The gills of the fish afford a good example of an aerating or respiratory apparatus. Here, water in which oxygen is dissolved is continually swept over an area in which numberless minute blood vessels ramify; the water gives up a portion of the oxygen dissolved in it, and receives in return carbonic acid from the blood stream; the two-fold object of respiration, the introduction of oxygen and removal of carbonic acid is thus effected.

34. **Mechanics of Respiration.**—In man the respiratory apparatus is extremely complex, because the gaseous interchange takes place in the interior of the body, and thus mechanical contrivances must be resorted to, in order to effect the continual introduction of fresh air, and the removal of that which is charged with impurities. The lungs, in which the changes take place, are situated in an air-tight chamber, the thorax, and communicate with the exterior by means of the trachea or wind-pipe. When the thorax expands the lungs expand with it, and as this leads to a reduction of pressure within the air spaces and passages of the lungs, which are in communication with the trachea, air rushes in to restore equilibrium. Similarly, when the thorax contracts the internal is greater than the external pressure, and air rushes out.

This action may be illustrated by taking the lungs of a sheep and placing them in a glass jar, the floor of which is formed by a sheet of indiarubber; the trachea is fitted into the neck of the jar in an air-tight manner. By a string attached to the centre of the sheet of indiarubber it is possible to increase at will the capacity of the jar. On pulling the string, the lungs at once respond to the diminution in pressure in the containing vessel, and they increase in size, air rushing in through the trachea; on allowing the floor of the jar to return to its old position, a corresponding quantity of air is forced out. In the thorax, however, the capacity may be increased in two ways. The floor of the thorax, the diaphragm, which normally projects somewhat into the chamber, may be flattened, and thus increases the capacity from top to bottom as in our illustration with the jar, and the capacity may also be increased from front to back by the raising of the ribs, which naturally

slant downwards from back to front, the result being to throw forward the front part of the chamber.

35. **Difference between Inspired and Expired Air.**—Ample evidence is afforded of the important changes going on in the lungs by the examination and analysis of air as it enters and leaves the mouth. By arranging two flasks, half-filled with lime water, as shown in Fig. 11, and connecting them together by means of a T tube, joined by one limb to a tube dipping under the liquid in one flask (*C*), by another to a short tube leading to the air in the other flask (*B*), and by means of the third limb (*A*) inspiring and expiring air through the apparatus, it is possible to pass all the air entering the lungs through the lime water in one vessel, and all the expired air through the lime water in the other. It is found that the air entering the lungs contains so little carbonic acid that no milkiness is produced in the lime water, but after a few expirations the lime water in the other flask becomes quite opaque through the copious formation of carbonate of lime, formed by the union of the carbonic acid with the lime water. If instead of lime water a solution of a substance, such as litmus, which will indicate the presence of an acid, is placed in the flasks, the expired air is seen to have a distinctly acid reaction, the blue litmus changing to red. No such change, however, is seen in the flask through which the air is inspired.

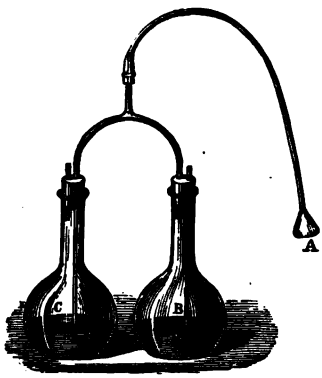


Fig. 11.

By the apparatus shown in Fig. 12, which was designed by Faraday, it can be proved that so much carbonic acid is present in expired air that it cannot support a burning candle. When the candle is burning in one of the glass cylinders it receives its supply of air by means of the other, which acts as a down-shaft. If the supply of air is then replaced by a gentle current of air from the lungs by breathing into the cylinder acting as the down-shaft, the flame flickers and goes out with all the characteristic symptoms of carbonic acid poisoning.

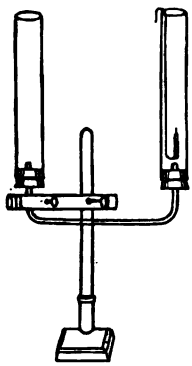


Fig. 12.

If a fair sample of expired air be analysed it is found to contain between 4 and 5 per cent. of carbonic acid, about 16 per cent. of oxygen, and 79 per cent. of nitrogen. Pure air contains ·04 per cent. of carbonic acid, 20·96 per cent. of oxygen, and 79 per cent. of nitrogen. The nitrogen remains, therefore, practically the same; the oxygen loses, and the carbonic acid gains, about 5 per cent. The amount of oxygen taken into the lungs is somewhat in excess of the carbonic acid given out.

36. **The Blood.**—If some freshly-shed human blood is received into a vessel, important changes soon go on; it becomes thick, and after a time separates into two distinct portions, a more or less solid clot and a yellowish liquid portion known as the serum. The clot is found to consist of threads of fibrin in which are entangled numberless small bodies, the corpuscles, which are of two kinds, white and red. The white corpuscle has an irregular outline, which in the living state is continually

changing in appearance, and contains within its jelly-like substance a body which has a more regular shape, the nucleus. The red corpuscle has a very definite outline, not unlike a round biscuit in appearance; it has no nucleus, and is much smaller than the white variety. The diameter of a red corpuscle is about $\frac{1}{3200}$th of an inch, its thickness being about $\frac{1}{12000}$th of an inch. The diameter of a white corpuscle is about $\frac{1}{2500}$th of an inch.

In a cubic millimetre of human blood there are, on an average, about 5,000,000 red corpuscles and 10,000 white corpuscles. The colouring matter of the red corpuscles is termed hæmoglobin; it is present in considerable quantities, constituting about 90 per cent. of the dried organic matter obtained from these bodies.

The serum consists of about 90 per cent. of water, 8 to 9 per cent. of organic matter, known as proteids, and about 1 per cent. of inorganic salts.

37. **Structure of Blood Vessels.** — When the heart contracts, the blood is driven with considerable force into the main arteries, the return of blood being prevented by valves, which guard the exits from the lower chambers or ventricles of the heart. In order to stand the sudden rush, and also withstand the pressure until the blood has been sent on through the body, it is necessary for the receiving vessels in the neighbourhood of the heart to have coats of considerable strength and elasticity. As these arteries break up into smaller and smaller vessels, so the pressure becomes less and less, and coincident with this there is a falling off in the elastic and muscular elements in the walls of the blood vessels. Eventually, when the branches have been re-

duced to the dimension of very fine twigs, these elements are entirely lost, and the vessels are represented by a layer of flattened epithelial cells continuous with the epithelial layer of the larger vessels. When this stage is reached the vessels are termed capillaries, and it is while the blood is passing through these that the all-important gaseous interchanges take place.

It has been calculated that in the lungs of a full-grown man there are 5000 miles of capillaries. These minute vessels then run together and form small veins; these are joined by others, and so on until they form the large vessels returning the blood to the heart. There is practically no pressure to withstand in the veins, and we find comparatively little muscular tissue in the walls, the thickness of which is less than in the case of arteries of the same bore.

On cutting a large artery the mouth gapes, and the blood issues in spurts; but in the case of a vein the blood pours out in a continuous stream, and the walls are not sufficiently rigid to maintain a cylindrical form. The epithelial layer common to arteries, veins, and capillaries, appears to exert an influence in keeping the blood in a fluid condition, any disease of this layer leading to the production of clots within the vessels. If a piece of a large artery is cut from a freshly-killed animal and closed at one end, and then blood is shed into the vessel so formed, it will not clot until the epithelial layer commences to degenerate.

With the exception of the pulmonary artery, carrying blood from the right side of the heart to the lungs, all arteries contain arterial or scarlet blood, whereas, with the exception of the pulmonary veins, bringing blood from the

lungs to the left side of the heart, all veins contain venous or purple blood.

38. **Minute Structure of the Lungs.**—The trachea on entering the thorax breaks up into two bronchi, each of which divides up again and again like the branches of a tree into the bronchial tubes, as shown in Fig. 13. In order to keep the trachea (*b*) continually open it is provided with circular bars of cartilage, the ends of which do not quite meet behind; the larger bronchial tubes also have cartilaginous rings, but in the smaller ones these have disappeared. The small bronchial tubes terminate in irregular expansions, the walls of which are honeycombed with conical bulgings, opening into these dilatations. These bulgings are termed the air-cells, of which there are said to be at least 600 millions in the lungs of a full-grown man. The external surface of these expansions at the terminations of the bronchial tubes are covered with networks of capillaries which ramify in all directions, passing down between the partitions separating adjoining air-cells. The blood passing through these capillaries is therefore exposed to the air contained within the spaces on either side, and from which it is separated only by the thin walls of the capillaries and the walls of the air-cells; the conditions are therefore eminently favourable for the interchange of gases.

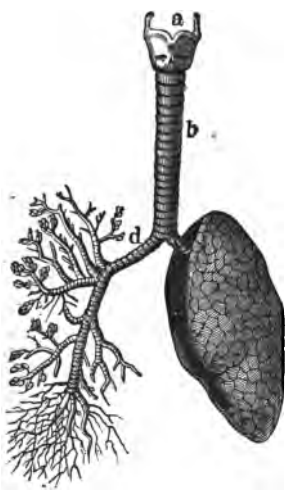


Fig. 13.

The lungs are supplied with blood by the pulmonary artery which brings it from the right ventricle of the heart. After branching in all directions the small arteries terminate in capillaries; these gather up again to form small veins which ultimately form the pulmonary veins, by which channels the aerated blood is conveyed to the left side of the heart. It is then pumped out by the left ventricle into the main artery, the aorta, from whence it travels through the other arteries to supply the needs of the body.

The epithelial cells which line the bronchial tubes are provided with little threads or cilia, which by their movements aid in the removal of foreign particles, which may find their way into the lungs in the inspired air.

39. **The Gaseous Interchange.** — There is always a certain amount of air, about 100 cubic inches, which cannot be removed from the lungs even after the longest expiration; this is termed the residual air. Under ordinary conditions there is in addition about the same volume, which is known as the supplemental air; the amount which is taken in at each inspiration, the tidal air, is about 30 cubic inches. Thus the volume taken in at each breath represents about one-eighth of the total volume in the lungs at the end of an inspiration. When a very deep inspiration is taken, another 100 cubic inches may enter the lungs; this is called the complemental air. It is evident, from the small volume of air taken in at each breath, that it cannot go far into the air passages of the lungs. It there comes into contact with the impure air for a very short time, the number of inspirations being normally 17 a minute; diffusion goes on rapidly, and the air on leaving is found to have lost from 4 to 5 per cent. of oxygen, and gained a like amount of carbonic acid. If,

from the point of contact with the tidal air, analyses could be made all along the route to the most remote air-cells in the lungs, the percentage of oxygen would be found to be less and less, and the carbonic acid would be found to have increased considerably.

If a sample of pure water is shaken up with oxygen gas, the water will absorb a definite quantity, depending upon the solubility of oxygen, the temperature, and pressure; but if under exactly the same conditions the water is shaken up with air, it is found that the amount of oxygen absorbed is only one-fifth of that in the former case; every molecule of gas coming into contact with the water in the first case would be oxygen, in the second case four out of five would be nitrogen. In other words the amount of pressure due to a particular gas regulates the amount of that gas absorbed by the water.

If we take a large vessel containing 10 per cent. of oxygen, 10 per cent. of carbonic acid, and 80 per cent. of nitrogen, and pour in a little pure water, this will take up certain quantities of these gases, depending upon their respective solubilities and the pressures they exert. On pouring this water into another large vessel containing say 19 per cent. of oxygen, 1 per cent. of carbonic acid, and 80 per cent. of nitrogen, the water will take up more oxygen, give off a large proportion of its carbonic acid, but the amount of nitrogen dissolved will remain the same; thus a liquid will absorb gases from its surrounding atmosphere, or give off dissolved gases, depending upon the constitution of the atmosphere and the gases dissolved in the liquid.

The laws which govern these changes apply strictly only to cases where there is no chemical action between the gas

and the liquid. When oxygen is taken up by the blood there is considerable evidence that loose chemical union takes place, and it is highly probable that the carbonic acid is also combined, but although there are important points of difference, the same general conditions affect the interchanges as in the case of solution. The blood in the capillaries of the lungs is exposed to a mixture of gases in the air-cells containing a large proportion of oxygen, and this is taken up greedily, out of all proportion to the solubility of the gas in water. The carbonic acid is however present in the blood in such large quantities that even supposing there to be 10 per cent. of this gas in the air-cells, the relative pressure is not sufficient for equilibrium, and the gas passes through the walls into the air-spaces, and so by diffusion is removed by the tidal air. The blood, thus deprived of a portion of its carbonic acid and enriched with oxygen, is returned to the heart and is distributed to the tissues of the body. Here, in passing through the capillaries, it is surrounded by a medium containing no free oxygen, but charged with carbonic acid; oxygen therefore leaves the blood in considerable quantities, and carbonic acid enters. During the gaseous interchange in the lungs the purple blood becomes scarlet, and in the tissues of the body the scarlet blood again becomes purple.

40. **Changes in the Blood.**—We have seen that the red blood corpuscles contain large quantities of a colouring matter, hæmoglobin. This is found to be the important agent in the blood in carrying oxygen from the lungs to the tissues of the body. If blood serum is added to water, and this is then shaken up with oxygen, the amount of the gas dissolved is not greater than in pure water under

the same conditions; the serum appears to have no effect whatever upon the solubility of this gas. If, however, some red corpuscles are added to the water, an increased capacity for dissolving oxygen is at once observed. That the hæmoglobin in the corpuscle is the active agent, can be proved by bringing oxygen into contact with the colouring matter separated from the corpuscles, when the same effect is produced. The product of the union of oxygen with hæmoglobin, oxyhæmoglobin, is of a bright scarlet colour, whereas the hæmoglobin, or, as it is often termed, reduced hæmoglobin, has a dark purple tint. The intermediate shades are due to varying proportions of hæmoglobin and oxyhæmoglobin present in the particular sample of blood. The loose nature of the chemical union may be proved by the easy removal of oxygen by bodies which have an attraction for this element; by the displacement of oxygen by substances having a stronger attraction for hæmoglobin, as in the case of poisoning by carbon monoxide, when carboxyhæmoglobin is produced; and by the fact that exposure of blood to a vacuum will result in the breaking up of the oxyhæmoglobin, the whole of the oxygen being removed.

It is, therefore, very easy to bring about the conversion of arterial into venous blood: thus, if arterial blood is shed into a strong aqueous solution of sulphate of magnesium to prevent it clotting, and to this is added a solution of ferrous sulphate, which greedily takes up oxygen to form a higher sulphate of iron, the scarlet colour is replaced by a dark purple. If the blood thus reduced is shaken up with air, oxygen is absorbed, and the original colour may be completely restored.

If water, to which red blood corpuscles have been added,

is exposed to an atmosphere of carbonic acid, it is found that the amount of the gas absorbed is of practically the same volume as it would have been under like conditions with pure water; but if serum is added, the water can take up a much larger quantity of this gas. Therefore, it is evident that the red corpuscle plays no direct part in the conveyance of this gas, but that it is carried by some body present in the fluid portion of the blood: this is probably sodium carbonate, which is a normal constituent of serum.

When carbonic acid is passed through a solution of sodium carbonate (Na_2CO_3), the gas is taken up with the production of sodium bicarbonate ($NaHCO_3$)—

$$Na_2CO_3 + CO_2 + H_2O = 2NaHCO_3.$$

It is probable that some such action as this goes on in the blood.

From 100 volumes of blood at 0° C. and 760 mm. about 60 volumes of gas may be obtained, consisting of oxygen, carbonic acid, and nitrogen; from arterial blood 20 volumes of oxygen, 40 volumes of carbonic acid, and 1 to 2 volumes of nitrogen are obtained; and from venous blood 8 to 12 volumes of oxygen, 46 volumes of carbonic acid, and 1 to 2 volumes of nitrogen.

Thus, in venous blood there is 6 per cent. more carbonic acid, and 8 to 12 per cent. less oxygen, than in arterial blood.

41. **The Warmth of the Body.**—When oxygen leaves the blood in the tissues it is at once stored in some loose form of combination. It, in some way imperfectly understood, renders the material with which it comes in contact unstable, and, during the activities of the body, complex bodies break down, producing among other sub-

stances carbonic acid, which is removed, as we have seen, by the blood stream. This breaking down of complex into simple substances produces an evolution of heat, by which the temperature of the body is maintained. In the deep-seated glands, where chemical change is most active, there is naturally the greatest evolution of heat.

The skin, on the other hand, is provided with numerous sweat glands, and when the superficial areas are flushed with blood, much water is poured out by means of these structures, and by its evaporation produces a cooling of these areas. By a marvellous arrangement the blood may be directed to these various regions in smaller or larger quantities by the constriction or relaxation of the small arteries, thus altering the bore. The heat is thus regulated, and an even temperature is maintained in the hottest day in summer and the coldest day in winter.

42. **Suffocation.** — The effect of continually breathing air in a confined space is to reduce the amount of oxygen and increase the amount of carbonic acid. As a consequence of this, the air in the air-cells cannot give to the blood sufficient oxygen, and there being a much greater pressure of carbonic acid, this gas cannot escape so readily from the blood stream. Increased inspiratory and expiratory efforts are made in order to remedy this, and become very violent as the blood becomes more and more charged with carbonic acid and the oxygen diminishes. Unless fresh air is admitted the body is soon thrown into convulsions, which are followed by a period of exhaustion, respiratory efforts become less and less frequent, and death results.

CHAPTER V.

VENTILATION.

43. **The Atmosphere — Sources of Impurity.** — The atmosphere is continually receiving immense stores of impurity from various sources, which, if allowed to accumulate, would soon render the air unfit for respiratory purposes. Powerful natural agencies are always at work removing in different ways the harmful elements. In some cases these are partially frustrated by the ingenuity of man in the construction of vast numbers of buildings on small areas, and so arranged that the air must necessarily become stagnant. The difference between the pallid child of the overcrowded city, and the ruddy child of the country village, affords good evidence in this direction of the result of successfully defeating natural means of air purification. If further evidence is needed, it can be found in the terrible rate of mortality, especially among children, in crowded quarters of cities, compared with similar rates in other parts of the city where this herding together does not take place. Of course, impure air is not solely responsible for this appalling difference; insufficient food and clothing, and other causes associated with great poverty play their part, but it is by far the most important factor. It is admitted by all authorities that in the production and propagation of disease, impure air is the most powerful and deadly agent.

The most important sources of impurity are respiration,

combustion, and the fermentation and decay of animal and vegetable matter. These are quite general: others are sporadic, as in the evolution of large volumes of gases and dust in volcanic and other eruptions; and in the neighbourhood of chemical and other manufactories there are local impurities associated with particular industries.

In respiration the chief impurities sent into the atmosphere are carbonic acid, organic matter, and aqueous vapour. In London alone, in twenty-four hours, over sixty million cubic feet of carbonic acid must be given off from the lungs of the people, in addition to vast quantities given out by animals. According to Dr de Chaumont, in a two-hours' meeting, 2000 people will give off from the lungs and skin 17 gallons of water, and as much carbonic acid as would be produced by burning a hundredweight of coal.

Combustion is a fertile source of impurities. If a candle is burnt in a dry glass vessel, the oxygen is soon used up, the candle goes out, and the interior of the vessel is covered with moisture, and on examining the gas left we find large quantities of carbonic acid. In burning coal and coal-gas, in addition to carbonic acid and water, which are the chief products of burning, other gases are given off, such as carbon monoxide, sulphuretted hydrogen, and sulphur dioxide, in quantities depending upon the kind of coal or gas and the method of burning. In London, over 30,000 tons of coal a day are consumed, leading to the production of about 90,000 tons of carbonic acid.

In the processes of fermentation and decay, large quantities of carbonic acid and water vapour are continually being poured into the atmosphere. The carbon stored in the plant and animal must find its way back into the atmosphere eventually in the form of carbonic acid, although its

return may be delayed in various ways for long periods of time.

If the bottom of a large vessel is covered with decaying animal or vegetable matter, and it is then closed up and left for a few days, and at the end of this time a candle is lowered into the vessel, the light is at once extinguished, because the oxygen has disappeared and its place has been taken by carbonic acid. It is impossible to calculate the amount of this gas produced daily in the atmosphere by these slow processes of burning or decay. Nitrogen is also given off as ammonia in large quantities during these putrefactive changes.

44. **Purifying Agents.**—In spite of all the impurities which are ever being poured into the atmosphere, the composition remains practically the same. Oxygen is being continually removed in processes of respiration, combustion, and decay, and yet the percentage by volume is rarely less than 20·9, and the amount of carbonic acid in open places scarcely ever goes beyond ·06 per cent., so powerful are the natural agencies of purification.

The wind sweeping through a town carries with it all kinds of unwholesome gases, some of these it mixes so efficiently with untainted air as to render them harmless. In other cases the action of the oxygen breaks up the poisonous organic vapours into simpler chemical bodies, and with this decomposition the poisonous nature is lost, even the living germ of disease under its action losing its virulence.

The action of the wind is not confined to open spaces. Beating against houses, it forces its way through porous bricks and crevices, and, mixing with the impure air, restores to it its value as a respiratory agent. Sweeping over

chimneys, it produces by suction a partial vacuum and thus increases the draught, and so the removal of impurities. This reduction of pressure further influences the entrance of fresh air at all available points.

Diffusion also takes an important part in the dilution of impurities, the activity of the molecules leading to uniformity of composition in masses of air. This will take place rapidly through any porous medium, and aid materially in purification if there is any considerable difference between the composition of the gases separated by the medium; the plastering and papering of walls interferes seriously with diffusion, but it still goes on through imperfect fittings. Roscoe found that when carbonic acid was set free in large quantities in a room, the amount was reduced in 90 minutes to half its former proportion by this process. Differences of temperature between the outside and inside of a room will lead to greatly increased diffusion through the walls, depending upon the nature of the material and the number of degrees difference in temperature. Thus, Pettenkofer found that in a room of 2650 cubic feet capacity, built of brick, when all crevices and openings were plastered up, 780 cubic feet of air passed through the walls in an hour, with a difference of 4° C.; 2650 cubic feet passed through in the same time with a difference of 19° C.; whereas, with a fire burning in the stove, with a difference of 19° C., the amount of air passing through the walls was 3320 cubic feet, showing an increase due to the draught of the stove of only 670 cubic feet per hour.

By means of volumes of air of unequal weight, caused by the expansion of air within buildings, circulation is produced, and by properly arranging entrances and exits ventilation becomes possible. The rapid expansion of air,

$\frac{1}{273}$ of its volume at 0° C. for 1° C., causes this effect to be felt with slight differences of temperature. If there is no definite point of entrance, the air enters through open doors, windows, holes, and crevices. Thus, differences of temperature act in a twofold manner in the purification of air—viz., by thermal diffusion and circulation of air.

Rain plays an important part in bringing to earth suspended bodies and gases which readily dissolve in water. An examination of rain-water shows the presence of solid matters and dissolved organic bodies, and gases which have thus been removed from the atmosphere. In all processes considered so far in the purification of air, the chief object obtained has been dilution of impurities with large quantities of pure air.

The amount of vapour in the atmosphere can never pass beyond a certain limit regulated by temperature, and is continually being deposited in some form. Poisonous vapours are oxidised, and solid particles find their way to the soil. Carbonic acid, however, would steadily accumulate and increase the average quantity in air, were it not prevented by the action of the green plant, of which this gas is the most important food; not only is the carbon stored in the plant, but oxygen equal in volume to the amount of carbonic acid consumed is restored to the atmosphere, so that an increase of carbonic acid and a diminution of oxygen are averted.

45. **Vitiated Air.**—Carbonic acid is always taken as the measure of impurity in a sample of air, but this gas chemically obtained from pure sources may be breathed in large quantities without producing any injurious effects. It does not produce fatal results until the amount passes beyond 50 parts per 1000. When, however, the carbonic

acid is produced by respiration, the result is very different; here it is associated with organic impurities which are very deleterious. Thus, the effect of breathing air containing 1·5 parts of expired carbonic acid per 1000 will be much the same as breathing 15 parts per 1000 of this gas from chemical sources.

The smell associated with expired organic matter gives a simple means of determining roughly the vitiation of the atmosphere in a room. When the amount of expired carbonic acid does not exceed 0·2 parts per 1000, the air is fresh and does not differ sensibly from the air outside; beyond this limit its influence is felt. When it reaches 0·4 parts per 1000, the air becomes rather close, and the organic matter becomes perceptible; with 0·6 parts per 1000, the air is close, and the organic matter becomes disagreeable; with 0·9 parts per 1000, the air is very close, and the organic matter offensive, and beyond this it is impossible to detect small differences by the sense of smell.

Authorities are agreed that air for breathing purposes should not contain more than 0·2 parts of carbonic acid per 1000 from respiratory sources; but the normal amount of this gas in the atmosphere is 0·4 parts per 1000, so that *the total amount should not exceed* 0·6 *parts per* 1000. *Air containing more than this is called vitiated air.*

46. **Breathing Space Required.**—In the chapter on Respiration we saw that under normal conditions a man breathes 17 times per minute, the amount given out at each expiration is about 30 inches, and that this air contains about 4 per cent. of carbonic acid. The amount of this gas given out varies considerably with different conditions, thus in Pettenkofer's experiments a man during repose gave out 0·56 of a cubic foot of carbonic acid per hour, whereas

in the day time it reaches 0·78 with normal exertion, and during hard work 1·52 cubic feet per hour.

In a mixed community the average amount of carbonic acid given off is about 0·6 of a cubic foot per hour, and this is made the basis of calculation for breathing space. It is evident that, since not more than 0·2 of a cubic foot of carbonic acid must be added to 1000 cubic feet of air if this is to remain harmless, each individual requires 3000 cubic feet of air per hour to mix with the amount of carbonic acid expired. If each individual has a breathing space of 300 cubic feet the air must be changed 10 times during the hour or it will become vitiated; whereas, with a breathing space of 500 cubic feet, it must be changed 6 times per hour, and with 750 cubic feet 4 times, and with 1000 cubic feet 3 times per hour.

With good methods of ventilation it is possible to change the air in a room 3 or 4 times during the hour under normal conditions, but it is difficult to go beyond this without producing draughts, and an unpleasant lowering of temperature when the difference between the external and internal temperatures is great. *Each individual should therefore have a breathing space of not less than 750 cubic feet.* Under the same conditions—*i.e.*, changing the air four times per hour, the relation of breathing space to quantity of carbonic acid is as follows:—

Breathing space	500	cubic ft. carbonic acid	0·7	parts per 1000
„	375	„	0·8	„
„	300	„	0·9	„

This makes no allowance for air vitiated by the products of combustion, whereas the amount of carbonic acid given off is considerable: thus, a common gas burner will burn

3 cubic feet of gas per hour leading to the production of more than 1½ cubic feet of carbonic acid.

47. **Estimation of Impurities in Air.**—The amount of carbonic acid may be accurately determined by shaking up a solution of baryta of known strength with a known volume of the air to be examined, and determining the amount of baryta destroyed by the carbonic acid by means of a solution of oxalic acid of the same strength as the baryta. The apparatus used for this purpose by the Author and Dr Barclay Smith, in a large series of experiments on the amount of impurity in the air of the London theatres and other large buildings, is shown in Fig. 14.

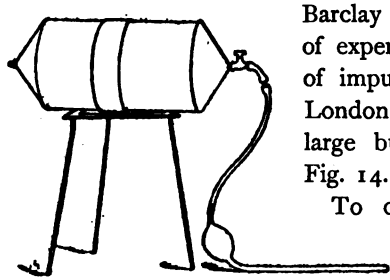


Fig. 14.

To one end of a copper cylinder of 5000 cc. capacity is attached a syringe by which the vessel is filled with the required sample of air; 100 cc. of baryta are then introduced, the taps turned, and the cylinder vigorously shaken to bring the baryta into intimate contact with the air. After remaining in contact long enough for the absorption of all the carbonic acid, the amount of alkalinity destroyed in 50 cc. of the solution is determined by means of oxalic acid. The baryta ($Ba(OH)_2$) is made of such a strength that 1 cc. is exactly neutralised by ½ cc. of carbonic acid to form barium carbonate ($BaCO_3$).

$$Ba(OH)_2 + CO_2 = BaCO_3 + H_2O.$$

The number of volumes of carbonic acid in 5000 cc. of air can thus be calculated.

The amount of organic matter can be determined by drawing a known quantity of air through distilled water, and then determining the amount of albumenoid ammonia as described in the analysis of water. It can also be determined by the loss of colour of a solution of potassium permanganate of known strength by drawing through such a solution a known quantity of air. When it is determined in this way, bodies such as sulphuretted hydrogen, which have the same power of destroying the colour of potassium permanganate, should be tested for, and, if present, an allowance made for their share of the action.

48. **Ventilation.** The object of ventilation is to prevent the air in an enclosed space becoming vitiated, or, in other words, reaching a larger proportion of carbonic acid than 0·6 parts per 1000 of air. In all schemes of ventilation the following conditions must be observed :—

(1) The entering air must be pure, otherwise a larger quantity will be necessary to do the work required, and, moreover, objectionable gases may be introduced.

(2) Draughts must be avoided—a current of air at 15° C. having a greater rate than 1 mile per hour or $1\frac{1}{2}$ feet per second is perceptible to some people, and air moving at a rate of $3\frac{1}{2}$ feet per second can be felt by all. An inlet of 24 square inches will admit 3000 cubic feet per hour, travelling at the rate of 5 feet per second, therefore an inlet of this size should be allowed for each person. With a good fire about 10,000 to 15,000 feet of air will pass up the chimney every hour.

(3) The entering air should not be far below the temperature of the room, or, if so, should be directed towards the ceiling so that it may mix with the warm air before its influence is felt.

(4) Short circuits from point of entrance to point of exit should be avoided. By this means draughts are produced and impure air has little chance of mixing by diffusion with the pure air: thus, when the fire-place is the chief point of exit, the incoming current should have an upward direction, or, if entering at the upper part of the room, should be distributed by obstacles placed in its path.

(5) Where the chimney is not used as point of exit, suitable outlets equal in size to the inlet should be placed in the upper part of the room, especially where products of combustion form part of the impurities of the air.

(6) The current of entering air should be constant, otherwise the limit of vitiation of the air is occasionally passed, though at other times it may be considerably below it.

(7) When an efficient scheme of ventilation with definite inlets is in operation, other possible means of entrance should, as far as possible, be closed. An open door, offering a path of less resistance to the incoming air, may prevent it passing through its proper channels.

(8) The inlets and outlets should be so arranged as to necessitate a thorough mixing of the pure and impure air, so that the composition at different parts of the room may be fairly uniform.

49. **Methods of Ventilation.**—If a current of air enters a room with a fair velocity in a definite direction, it will continue to move in that direction unless the weight of the entering air is much greater, volume for volume, than the air of the room, in which case it will fall before thorough mixing has taken place. A scheme of ventilation which will act perfectly with a difference between the external and internal temperatures of 5° C., may be a complete failure with a

difference of 20° C.; but with great differences of temperature natural ventilation, such as thermal diffusion, is so much more active, that artificial methods may be partially dispensed with. Methods of ventilation in which the entering air is not directed upwards are practically useless, unless by means of obstacles the air is efficiently distributed.

In the Hinckes-Bird window ventilator, Tobin's tubes, and the Sherringham valve, the current of air is given an upward direction. Where the fire-place is opposite the window in a room, the Hinckes-Bird ventilator generally gives excellent results, and the simplicity of the method makes it generally applicable. The lower sash is raised, and a solid piece of wood placed in the lower part of the framework of the window, so that the sash fits upon it in an air-tight manner. The only way in which air can then enter through the window is between the upper and lower sashes, and if the channel thus formed is about three inches deep the air entering the room will be given a definite upward direction, and will mix thoroughly with the air in the upper part of the room before leaving at the fire-place, as shown in Fig. 15.

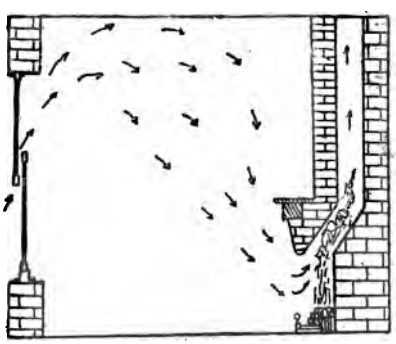


Fig. 15.

A wide sheet of air thus continually playing over the top of the room will change the air at least 4 times per hour.

Vertical holes are sometimes bored in the bottom rail of the upper sash of a window, and, provided the rail is deep

enough to give the air a sufficiently definite direction, it may prove a fairly successful method of ventilation.

In the Tobin's tube the air enters through a grating by a horizontal portion at the level of the floor, and is then conducted up a vertical tube 4 to 6 feet high; the air is thus directed towards the ceiling (Fig. 16). In the horizontal tube water may be placed to purify the entering air, or it may be filtered through cotton wool.

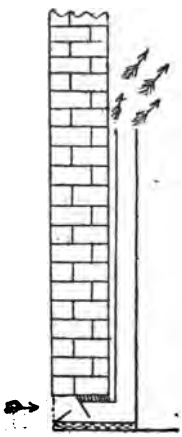


Fig. 16.

When the entering air is very cold it may fall before distribution has taken place; the tube is then partially or entirely closed by a lid over the tube provided for the purpose.

Sherringham's valve is so arranged that air, coming through a grating in the wall into an iron box, may be given an upward direction by a valve hinged along its lower edge in the front part of the receiving chamber. By a regulating arrangement the valve may be closed or only partially opened. The size of the inlet opening is generally 9 inches by 3, giving an area of 27 square inches. According to Parkes no inlet should have a greater area than 48 to 60 square inches, and no outlet a greater area than one square foot.

The methods of ventilation considered are well adapted for dwelling-rooms, and, with a breathing space of 750 cubic feet per individual, it is not difficult to keep the air below the standard of vitiation. Where large buildings are concerned, in which great numbers of people congregate, it is found impossible to keep down the amount of car-

bonic acid to the proper proportions. In the most recent analyses made of the air in London theatres, where great attention had been paid to ventilation, and the places were lighted throughout with the electric light, it was found that when the performance had been on a couple of hours, the carbonic acid was rarely less than 1·2 to 1·6 parts per 1000 of air.

In the ventilation of large buildings, or rooms which have no apartments over them, where direct communication can be made through the roof, Mackinnel's ventilator (Fig. 17) may be used. This consists of a long central cylindrical shaft, which serves as an outlet, enclosed by another shorter cylinder which forms the inlet. By placing a gas jet beneath the central shaft the heated air rises through the tube, which is protected on the outside by some form of covering to prevent the wind blowing down. The air passing into the room by the outer tube is warmed by contact with the inner one, and is distributed by means of a horizontal rim attached to the lower part of the outlet tube. After thus passing over the upper part of the room it passes down by the walls, and eventually finds its way to the outlet shaft. If there is a fire in the room, the central tube should be closed, otherwise both shafts become inlets. With the window open both become outlets.

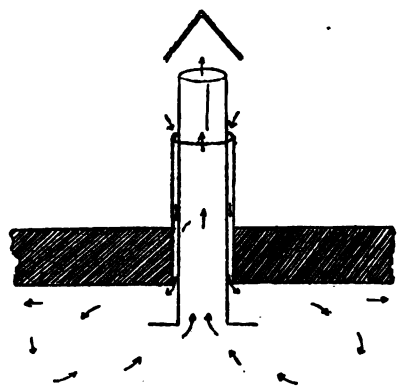


Fig 17.

In Sylvester's scheme of ventilation the air enters by a large tube fitted with a hood or cowl facing the wind. After passing over a warming apparatus, it is distributed by a system of pipes to the various rooms of the house. A similar set of outlet pipes communicate with main pipes leading to the outside; here they are provided with cowls with their backs to the wind, which, in blowing over them, produces a partial vacuum in the pipes, and draws the impure air out of the rooms.

Systems of ventilation which depend for supply and removal of air upon the action of the wind are not, however, satisfactory. When the aspirating action of a current of hot air passing up a high tower is used instead of the wind, and a network of outlet pipes from different rooms communicate with the main shaft, a constant removal is effected, and if by a similar network of inlet pipes the air is drawn in over a heating apparatus, perfect results may be obtained, not only with regard to the purity of the air, but also with regard to uniformity of temperature throughout the house.

In large buildings air is often pumped out by means of extracting fans placed in the main outlet shaft. In other cases it is propelled into buildings by means of fans, and in some cases excellent results are obtained. Thus, in the Hospital Lariboisière in Paris, about 5000 cubic feet per head per hour have been introduced by means of a propelling fan, assisted somewhat by natural ventilation. By warming or cooling the conducting pipes in this method of ventilation, it is possible to keep the air in a building at any required temperature.

Extraction and propulsion methods of ventilation are especially useful where there is little difference between

the external and internal temperatures, and where otherwise the air would be stagnant. The punkah, used so much in India, is a combination of the two methods: air is moved on, and fresh air comes in to take its place. By moistening the punkah a cooling effect is also produced by evaporation.

50. **The Effect of Vitiated Air on Health.**—The effect of continually breathing impure air is to produce pallor, listlessness, loss of appetite, and to render people especially liable to the various forms of lung disease. People who live much in the open air, such as gardeners, fishermen, farmers, and agricultural labourers, are the healthiest, and have the lowest death-rates. The death-rate from phthisis or consumption among these people is only half that of the male community generally.

There is a wealth of statistics showing the connection between a bad state of health and the impurity of the atmosphere breathed. Wilson reports, in his hand-book of Hygiene, that in cells always occupied in the Portsmouth Convict Prison, with a breathing space of 614 feet, the air of which contained 0·72 parts of carbonic acid per 1000, the prisoners were healthy and had a good colour. In other cells, occupied only at night, with a breathing space of 210 cubic feet, the average amount of carbonic acid being 1·044 parts per 1000, the prisoners were all pale and anæmic. Here all the other conditions as to food, discipline, and employment, were the same in both cases. The most striking case is that of a badly ventilated prison, and well ventilated House of Correction, in Vienna, where the deaths recorded for the same period, extending over several years, were as 88 to 14, and the deaths from phthisis were as 51 to 8 respectively. The high death-rates from phthisis among soldiers, sailors, and prisoners were notorious until

radical changes were made in barracks, ships, and prisons, in the amount of breathing space allotted per man, and in the ventilation. In the present day, these classes of people enjoy a comparative immunity from this disease.

The tendency to cold is also greatly increased by living in a vitiated atmosphere, which lowers the general tone of the system. Thus, in the Crimean War, the soldiers who lived in tents in the bitterest weather were free from colds, but with those who lived in badly ventilated huts they were very common.

Another important point, in connection with the influence of vitiated air on health, is the vast increase in the number of bacteria in vitiated air. In the streets of Paris the average number of bacteria per metre of air is 3480, whereas in inhabited rooms there may be 10 to 20 times this number. The transference of germs of disease from place to place by means of vitiated air is of common occurrence, hence the necessity of isolation in cases of certain diseases. Pasteur has proved the effect of pure air in rendering pathogenic bacteria harmless, and it becomes of the utmost importance that the air in sick rooms should be continually changed.

In the cattle plague of 1866, where the cattle were placed in well ventilated sheds, only about one-third died, whereas nearly all those in badly ventilated places succumbed. Where, in addition to respiratory impurities, the air contains solid particles in suspension in the form of dust, the necessity for good ventilation is increased. These particles, especially if they are angular, produce serious lung mischief.

Sir J. Simon, in one of his reports, stated that miners, with the exception of those in the well ventilated mines of

Durham and Northumberland, break down as a class prematurely from bronchitis and pneumonia, caused by the atmosphere in which they live. Among the Cornish miners two-thirds of the total mortality is due to lung disease, the death-rate being nearly three times as great in this respect as among Cornish males generally.

CHAPTER VI.

WATER.

51. **Hydrogen—Preparation and Properties.**—Hydrogen is generally prepared by the action of dilute sulphuric acid (H_2SO_4) on zinc (Fig. 18). The zinc replaces the hydrogen

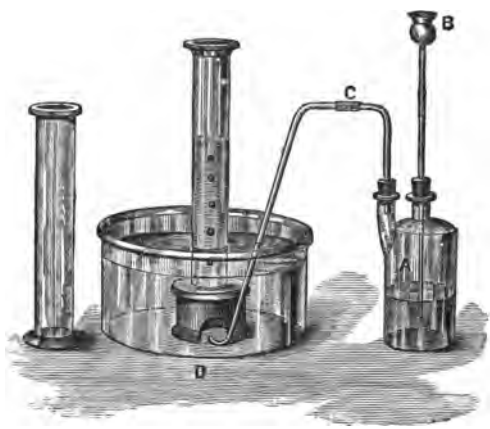


Fig. 18.

in the acid forming a salt, sulphate of zinc ($ZnSO_4$), which is left in solution in the generating flask (*A*).

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

The gas is collected over water (*D*), in which it is only sparingly soluble. It is a colourless, tasteless, odourless gas,

and will burn readily to form water, but will not support combustion. If a jar of this gas is held mouth downwards, and a light applied, it burns with a colourless flame at the mouth of the vessel. If, however, a lighted taper is pushed up into the gas, it is at once extinguished, and can be rekindled at the mouth. Hydrogen is the lightest gas known.

A mixture of hydrogen and air will explode with considerable violence. If a cold vessel is held over a burning jet of this gas, drops of water are formed by the union of hydrogen with the oxygen of the air.

$$H_2 + O = H_2O.$$

52. **Water a Compound.**—In the atmosphere we found that the nitrogen and oxygen were not united, and that the properties of the mixture were intermediate between the properties of the constituents. In water we are dealing with a chemical compound of hydrogen and oxygen, the characteristic properties of the constituent gases having entirely disappeared. Thus oxygen is the great supporter of combustion, and hydrogen is a highly combustible body, but water has neither of these properties. The composition of this body is absolutely constant, and it can only be separated into its constituents by an expenditure of energy equal to that given out in the form of heat in its production.

In all questions of life and health water plays a prominent part. In a pure state it forms a necessary element of everyday life, the health of a community depending largely, among other things, upon a good water supply. In consequence of its great power of carrying bodies from place to place in suspension and solution, it may become, in an impure state, a most powerful agent in the spread of disease.

53. **Composition by Weight.**—Water consists of 8 parts by weight of oxygen united with 1 part by weight of hydrogen. To prove this, hydrogen is generated in a flask (*A*, Fig. 19) by the action of sulphuric acid upon zinc, and the issuing gas dried by passing through a U tube (*B*), filled with calcium chloride; the dry gas then passes over some heated copper oxide (CuO) in a strong piece of glass tubing (*C*). The hydrogen unites with the oxygen of the copper oxide to form water, which is collected in

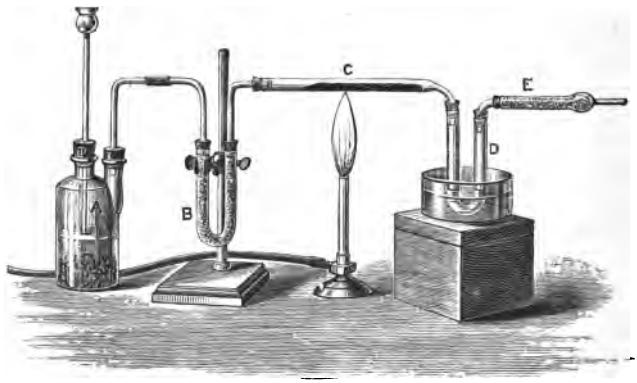


Fig. 19.

a U tube (*D*), to which is attached a tube (*E*) containing calcium chloride, to prevent any vapour escaping; the copper oxide is reduced by the action of the hydrogen, and bright metallic copper is left in the tube (*C*).

$$CuO + H_2 = H_2O + Cu.$$

Since the hydrogen gas is perfectly dry on entering *C*, it is evident that all the water contained in *D* and *E* must have been produced by the action of hydrogen on copper oxide. The increase in weight of *D* and

E will give the amount of water formed, and the loss in weight of *C* will represent the amount of oxygen used; the difference between the water produced, and the oxygen which has been lost, will be the amount of hydrogen entering into combination.

Gain in weight of *D* and *E*	= 36 grains.
Loss in weight of *C*	= 32 „
Difference representing the hydrogen	= 4 „

Thus, according to the above experiment, 4 grains of hydrogen have united with 32 grains of oxygen to form 36 grains of water.

54. **Composition by Volume.**—The composition of water by volume may be proved in a variety of ways.

If an electric current is passed through some water acidulated with sulphuric acid, as in the apparatus shown in Fig. 20, bubbles of gas at once appear on the platinum plates, and rise to the top of the tubes, displacing the water. At the plate attached to the positive (+) end of the galvanic battery, oxygen is given off, because this gas is electro-negative; and at the plate attached to the negative (−) pole the electro-positive element, hydrogen, is evolved. The volume of gas given off at the negative pole is twice as great as at the positive pole, the relation of the volume of hydrogen to oxygen in water being two to one; this is, however, not an exact method of proving the composi-

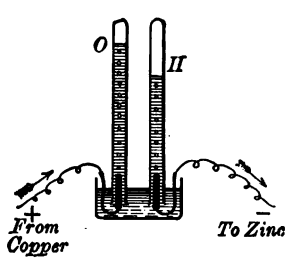


Fig. 20.

tion by volume. The chief sources of error are—(1) the oxygen is more soluble in water than hydrogen; (2) a small quantity of ozone is produced; and (3) the platinum plate at which the hydrogen is given off absorbs small quantities of this gas.

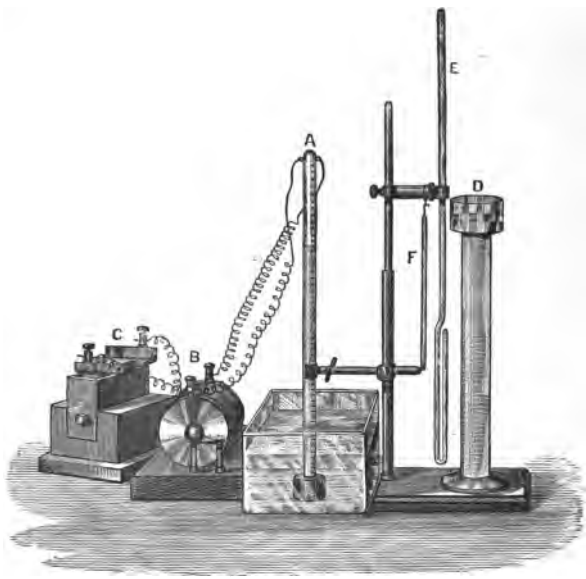


Fig. 21.

The most exact method of determining the composition by volume is to explode a mixture of the gases in a eudiometer tube. For this purpose some hydrogen gas is introduced into a eudiometer (*A*, Fig. 21) filled with mercury, and the volume noted; oxygen is then introduced, and the volume of the mixed gases read off. The bottom of the tube is then pressed down on an india-rubber pad, to prevent

any escape of mercury when the mixture is exploded, and the platinum wires of the eudiometer are attached to the coil (*B*), which is connected with a voltaic battery (*C*); a spark is then passed across the wires, and a flash is seen in the tube. On removing the pad the mercury rises in the eudiometer, and when the temperature of the remaining gas is at the temperature of the room, the volume is read off. The volumes in each case are reduced to 0° C. and 760 mm. pressure (p. 51).

Result of experiment—

Volume of hydrogen = 50 cc.
Volume of hydrogen and oxygen = 80 cc.
Volume of oxygen left after firing = 5 cc.

Since 30 cc. (80 − 50) of oxygen were added, it is evident that 50 cc. of hydrogen have united with 25 cc. of oxygen to form water, the volume of which can be neglected. The proportion by volume is therefore 2 of hydrogen to 1 of oxygen.

If the gases had been fired at a temperature above the boiling point of water, steam would have been formed, in which case the final volume would have been 55 cc.—50 cc. of steam and 5 cc. of oxygen; because 2 volumes of hydrogen unite with 1 volume of oxygen to form 2 volumes of steam.

$$2H_2 + O_2 = 2H_2O.$$

The relation by weight can be deduced from the relations by volume; for, since two molecules of hydrogen unite with one molecule of oxygen to form water, and the oxygen molecule is 16 times heavier than the hydrogen molecule, the relation by weight must be 2 to 16 or 1 to 8.

55. **Three States — Solid, Liquid, and Gaseous.** —

Water exists in three distinct physical conditions, though no change takes place in chemical composition: thus, 9 grains of ice, water, or steam will yield 1 grain of hydrogen and 8 grains of oxygen. Under normal conditions of pressure, temperature alone determines the physical state. At temperatures below 0° C. water is solid, between 0° C. and 100° C. it is liquid, and beyond 100° C. it is gaseous.

The molecular condition in these three states is widely different. In the solid state, the molecules have a very limited power of movement, which is confined to a definite area. The molecules in one part of a block of ice cannot change places with those in another; but directly the ice is converted into liquid, they can move with the greatest freedom among each other, the limits of these movements being the bounding surface of the water, and even across this surface the molecules occasionally pass, the number increasing with the temperature.

When the boiling point is reached—that is, when the shower of molecules of water passing across the bounding surface exerts a pressure equal to the pressure of the atmosphere, perfect freedom of the molecules is obtained; no cohesive force exists between them, and they can only be confined in a vessel which encloses them on every side. The conversion of water into steam is delayed by increasing the pressure on its surface, and hastened by reducing it. Thus, at the bottom of a deep mine the temperature of the boiling point of water is raised, while at the top of a mountain it is lowered. In some cases, as at great altitudes, the boiling point of water is so low that cooking operations cannot be carried on successfully in open vessels, and to remedy this, closed vessels with weighted lids are used to artificially increase the pressure, and thus raise the tempera-

ture of the boiling point. The boiling point of water is generally stated to be 100° C. or 212° F., but this is only when the barometer stands at 760 mm. With a high barometer it is above this temperature, and with a low barometer, below it. *Water boils when the tension of its vapour equals the pressure to which it is subjected.*

56. **Latent and Specific Heat.**—If a block of ice below the freezing point is heated, the temperature is raised regularly, like an ordinary solid, until 0° C. is reached. The solid is then gradually converted into the liquid state, and, though a large amount of heat is applied, no change of temperature takes place until the whole of the ice has disappeared. The heat which is thus absorbed on change of state, without alteration of temperature, is termed *latent heat.* The amount of heat rendered latent on the conversion of a pound of ice at 0° C. into a pound of water at 0° C. is sufficient to raise 80 pounds of water through 1° C. Thus, if a pound of water at 0° C. is mixed with a pound of water at 80° C., two pounds of water at 40° C. are produced; whereas, if a pound of ice at 0° C. is mixed with a pound of water at 80° C. the result is two pounds of water at 0° C.: the whole of the heat given out by a pound of water in falling from 80° C. to 0° C. having been used up in converting a pound of ice at 0° C. into a pound of water at the same temperature.

Similarly, it can be proved that a pound of water at 100° C. in passing into steam at 100° C., requires as much heat as would raise 536 pounds of water from 0° C. to 1° C.

When steam passes into water, and water into ice, amounts of heat are given out exactly equal in value to those absorbed during the reverse changes. This absorption, or evolution, of heat on change of state is of the greatest im-

portance in Nature. Life in cold mountainous districts would be impossible if, when the temperature passed above the freezing point, the collected masses of snow and ice were suddenly converted into water, thus producing disastrous floods. In the same way, if no heat were absorbed in passing from water into steam, cooking operations would be attended with considerable difficulty, due to the sudden conversion of water into 1600 times its volume of steam on reaching the boiling point.

The passage from water to ice is a very slow process, due to the large amount of latent heat given out; without this, lakes would rapidly become huge blocks of ice when the temperature fell much below the freezing point.

Similarly, the sudden conversion of vapour into water in the atmosphere is held in check by the evolution of latent heat during the transition from one state to the other.

The specific heat of a body *is the ratio of the amount of heat required to raise its temperature to the amount required to raise the same mass of water through the same range of temperature.* Thus, the amount of heat required to raise a pound of water from 0° C. to 1° C. will raise a pound of mercury from 0° C. to 30° C.; the specific heat of mercury is therefore $\frac{1}{30}$. The high specific heat of water makes it of great value as a cooling agent, because it brings down the temperature of other bodies without its own being raised to any considerable extent. If a pound of mercury at 100° C. is mixed with a pound of water at 0° C., the resulting temperature is only about 3° C., though the temperature of the mercury has been reduced 97° C. The cooling effect of water is also due in many cases to the large amount of heat absorbed in its evaporation, which is taken from the body with which it is in contact at the time.

57. **Changes in Volume—Importance of these in Nature.**—When a block of ice far below the freezing point (say $-100°$ C.) is heated, it expands regularly until the melting point, 0° C., is reached. A contraction then sets in, so that 109 cubic inches of ice at 0° C. only produce 100 cubic inches of water at the same temperature. On heating further, the water contracts until it reaches 4° C., which is termed the point of maximum density of water. After this, water expands regularly until it reaches the boiling point, when it expands to about 1600 times its original volume. On further application of heat, the steam expands like an ordinary gas (p. 50). These changes are reversible; thus on cooling steam at 100° C., it is converted into $\frac{1}{1600}$th of its volume of water; and if further cooled, the water contracts until 4° C. is reached, and then expands to the freezing point, when a sudden expansion takes place, 100 volumes of water producing 109 volumes of ice, and then the ice contracts regularly as a solid.

Some of these changes in volume, with alteration of temperature, are of the greatest importance in Nature. The expansion which takes place on water becoming ice plays an all-important part in breaking up the rocks on the earth's surface. The water passes into the crevices of the rock, and when the temperature falls below 0° C., expansion takes place, and the crevices are widened; this continues until separation is effected. This action is also continually going on in small pieces which have been split off, and this, together with the action of rain, reduces the rock to a soil suitable for plant life.

The remarkable action of water in shrinking until 4° C. is reached, and then expanding to the freezing point, makes life in our lakes and rivers possible. The point

of maximum density of water was investigated by Dr Hope, who used an apparatus similar to that shown in Fig. 22. Two thermometers were fitted horizontally into a glass cylinder which was filled with water, and a gallery was fixed round the cylinder about half-way between the points where the thermometers were inserted. The gallery was filled with ice; the temperature of the room being 15° C. At the commencement of the experiment both thermometers registered the same temperature, but as the stratum of water at the level of the ice became cooled, the water became heavier and sank to the bottom, affecting only the lower thermometer. This continued until a temperature of 4° C. was reached, the water round the upper thermometer still being practically at the temperature of the room. As the water was cooled further it expanded and rose to the top, affecting only the upper thermometer. This continued until it stood at 0° C., the lower one still registering 4° C. This is continually going on in lakes and rivers during the winter. The cooled water sinks until the temperature reaches 4° C.; after that, being lighter, it remains at the surface: the first layer of ice is therefore formed at the top. During a hard winter the water at the bottom of a deep lake rarely sinks below 3° C. If the water continued

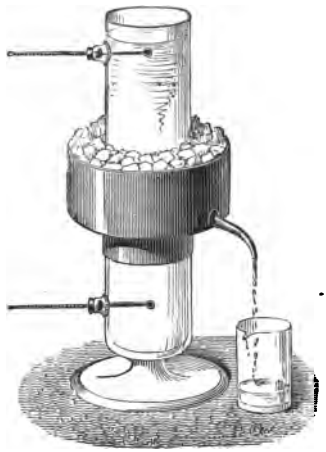


Fig. 22.

to shrink to the freezing point, the first layer of ice would be formed at the bottom, and the lake would eventually become one mass of ice.

58. **Solubility of Solids and Gases in Water.**—If water is taken from any natural source and heated, it will give off bubbles of gas, and, on evaporation, will leave a solid residue. The most common gases dissolved in water are carbonic acid, oxygen, and nitrogen. The solids vary with the district from which the water is taken: salts of lime, magnesium, and sodium are of most frequent occurrence. A portion of the residue left on evaporation will burn away on exposure to a red heat; this is the organic matter, and may consist of solid particles in the water, or dissolved matter, or both. The presence of gases dissolved in water affects its power of dissolving solids. Thus, carbonate of lime is practically insoluble in pure water, but may be dissolved in large quantities by water containing carbonic acid. This may be proved by passing a stream of carbonic acid into a vessel full of lime water. It at once becomes milky, due to the formation of carbonate of lime, but if the current of gas is continued, the water becomes charged with carbonic acid, the carbonate of lime dissolves, and the liquid again becomes clear. On boiling this clear solution, the carbonic acid is driven off, and the water is no longer able to hold the carbonate of lime in solution, and it is deposited as a solid. This is the explanation of the "fur" deposited in kettles by driving off the carbonic acid from the water.

59. **Hardness of Water.**—Soap consists of sodium or potassium salts of stearic, oleic, or palmitic acid. These salts are very soluble, and when dissolved in water will produce a lather which has valuable cleansing properties. If water contains substances in solution which will produce

insoluble salts with the soap, the water is said to be hard, and no lather can be formed until the whole of these compounds have been satisfied, thus—Sodium stearate + calcium carbonate = calcium stearate + sodium carbonate. Insoluble bodies, such as calcium stearate, form the gritty substances produced in washing with hard water. The principal salts present in water which produce hardness are chloride, sulphate, and carbonate of lime, and carbonate and sulphate of magnesium.

We have seen that the presence of carbonic acid has a great influence on the solubility of carbonate of lime. Hardness due to this body is therefore termed temporary hardness; because, on the removal of this gas by boiling or by the addition of lime water, this compound is precipitated. The other substances are not affected by carbonic acid, though magnesium carbonate is generally stated to be, and the hardness produced by them is termed permanent hardness.

The hardness of water is generally estimated in England in grains per gallon. It is inconvenient, however, to take such a large quantity for this determination, so a smaller amount is taken, but the same relationship is retained.

A gallon of water weighs 10 pounds, or 70,000 grains; we must therefore estimate the hardness in parts per 70,000.

For this purpose a solution of soap is taken of such a strength that 1 cc. will exactly neutralise a milligram of carbonate of lime, and the amount of water taken for the determination is 70 cc., which is equivalent to 70 grams, or 70,000 milligrams, since 1 gram is equal to 1000 milligrams. By this means the number of milligrams of carbonate of lime in 70,000 milligrams of water is found, which is the same as grains per gallon.

If 70 cc. of pure distilled water are taken, 1 cc. of soap solution is required to produce a lather; therefore 1 cc. must be taken from the number used in an ordinary determination to get a true result.

In an actual experiment, 16 cc. of the soap solution were required to produce a permanent lather—that is, one which will last for five minutes, in 70 cc. of water, therefore, the total hardness was 15 (16 – 1) grains per gallon. On boiling for one hour to precipitate the carbonate of lime, and making up the volume of water lost by evaporation with distilled water, 70 cc. required 8 cc. of soap solution to produce a permanent lather; therefore the permanent hardness was 7 (8 – 1) grains per gallon: the result was, therefore, total hardness 15 grains per gallon, 8 being due to temporary, and 7 to permanent hardness.

Where the water contains much magnesium salts these have to be determined separately, after precipitation of the lime salts by means of ammonium oxalate.

The effect of hard water upon health is a much debated question. It appears to depend largely upon the personal equation of the individual. Water containing more than 15 degrees of hardness affects many people, others are affected by much less than this. It has a decided effect upon horses, producing indigestion, and making the coat rough.

60. **Organic Impurities in Water.**—The determination of the amount of organic impurity in water is a matter of the greatest importance, as water containing an excess of such impurity becomes a suitable home for vegetable organisms, which play such an active part in the spread of disease. Various methods have been suggested for the

estimation of organic matter, but the one which excels all others is the ammonia-process, by which the amount is determined, by finding how much nitrogen can be obtained in the form of ammonia from a known quantity of the sample of water.

In this process it is necessary to distinguish between, (1) ammonia present in the water in the free state, or combined in inorganic salts, such as ammonium carbonate, which is always present when water is contaminated with urine, the urea being converted into this compound; and (2) ammonia obtained from the breaking up of complex organic compounds such as proteids, which contain about 15 per cent. of nitrogen.

The first is termed free ammonia, and can be obtained from the water by boiling it with sodium carbonate, which has no effect upon the organic matter. After all this has been driven off, a strong solution of potassium permanganate and caustic potash is added, which breaks down the organic matter, and the nitrogen is evolved as ammonia, which is termed the albumenoid ammonia.

For the purposes of analysis 500 cc. of water are taken and heated in a distilling apparatus (Fig. 23). Water from *a* passes continually through the tube surrounding *tt'*, keeping it cool, and so effects the condensation of steam coming from the retort. Some pure sodium carbonate is added to the water in the retort, and, on boiling, the free ammonia is given off with the steam, which is converted, on cooling, into water containing the ammonia in solution. This is collected in small jars, which should hold about 50 cc.

The amount of ammonia in these jars is determined by means of Nessler's solution, which consists of potassium

iodide, mercuric chloride, and caustic potash, and which gives an orange coloration with this body, the tint varying with the quantity of ammonia present.

The amount is determined by taking 50 cc. of pure distilled water in a similar jar, and adding a solution containing a known quantity of ammonium chloride until it gives exactly the same tint with Nessler's solution: the

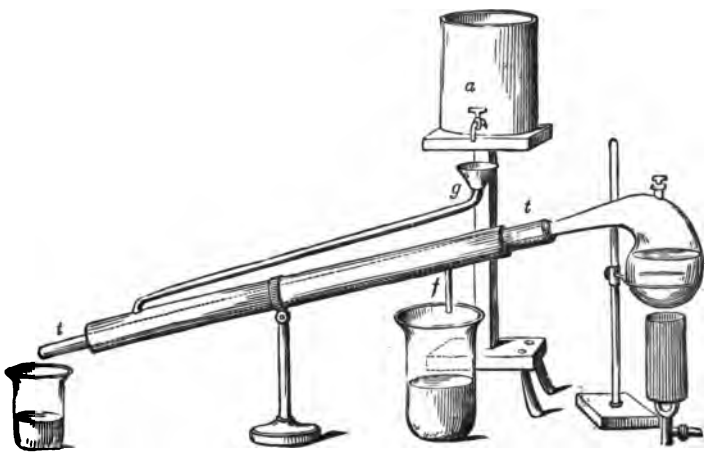


Fig. 23.

exact point is readily found by placing the two jars together on a white slab, and looking through the columns of liquid against the white surface. After the amount in the first jar has thus been determined, the second jar is taken, and so on until the water collected contains no ammonia. By seeing how much of the solution of ammonium chloride of known strength has been used altogether to give the required tints, we can readily calculate how much free ammonia was present in the 500 cc. of water taken. To the water left

in the retort a solution of potassium permanganate and caustic potash is added, and, on boiling, ammonia again appears in the distillate. The amount is determined by means of Nessler's solution as before, and thus the amount of albumenoid ammonia is determined.

The water supplied to London by the Kent Company, which is derived from deep springs, is exceedingly pure, and gave on analysis—

Free ammonia, . 0·01 parts per million of water.
Albumenoid ammonia 0·02 „ „

When the free ammonia exceeds 0·08 parts per million of water, it is generally due to sewage adulteration; and a water containing more than 0·15 parts per million of albumenoid ammonia is unfit for drinking purposes. According to Wanklyn, a good water should not contain more than 0·06 to 0·08 parts of albumenoid ammonia per million of water.

A good rough test for the presence of organic impurity in water is to add to it a solution of potassium permanganate until a definite pink tinge is obtained, and make it acid with a few drops of sulphuric acid. On standing some time, if the water is impure, the colour will disappear or change to a dirty brown: organic matter from animal sources will decolourise it quickly, while that of vegetable origin acts very slowly. If the water is heated, the colour is destroyed much more rapidly. If no change takes place in 24 hours, the water is practically free from organic matter.

If iron salts, or nitrates are present in the water, they will also destroy the colour of the permanganate, but these can be recognised by individual tests.

61. **Metallic impurity in Water.**—The most common

metallic poison in water is lead, obtained from lead pipes through which the water passes. The evidence as to the causes which bring about the solution of lead in water is somewhat conflicting, but it appears certain that water containing much oxygen has a considerable action in this direction, and that this is increased by the presence of organic matter. Water charged with carbonic acid, however, soon forms on the inside of the pipes a coating of insoluble lead carbonate, which protects them from further action. Such a water should be allowed to run through new pipes for some time before the water is used for drinking.

A very small quantity of lead in water may produce lead paralysis. Cases are quoted in which the water contained only $\frac{1}{100}$th of a grain per gallon; but when it reaches $\frac{1}{10}$th of a grain per gallon, most people are injuriously affected by it. In the case of the lead poisoning of Louis Philippe's family at Claremont, by which 34 per cent. of the people taking it were affected, the water contained $\frac{7}{10}$ths of a grain of lead per gallon.

CHAPTER VII.

THE SPREAD OF DISEASE BY IMPURE WATER. BACTERIA.

62. **Epidemics and Impure Water.**—The most important factor in the spread of disease is, with the exception of impure air, impure water. The fact that the vegetable germs of disease find in it not only a suitable medium for active propagation, but also a favourite method of transference from point to point, is now placed beyond all doubt. During outbreaks of epidemics the virulence appears to vary with the state of impurity of the water; and where a community in a particular district is supplied with water from different sources, the death-rate in houses supplied with the purer water is invariably lower than in those with an impure water-supply. The terrible connection thus existing may be shown by comparing analyses of water in the same city, during such outbreaks, with the death-rate. If a curve representing the impurity at different times be drawn, and another for the same period be drawn representing the death-rate, the curves are found to agree in all essential particulars.

The convict prison at Millbank, on the Thames, had a tainted water-supply till the latter part of 1854, and the death-rate for twelve years previously had averaged 33 per 1000. When a pure water-supply was introduced, though all the other conditions remained the same, the death-rate

at once fell, and for a subsequent period of fifteen years averaged 12 per 1000.

Glasgow drew its water-supply from the Clyde till 1847, when it was replaced by pure water from Loch Katrine; this led at once to a reduction in the death-rate, and a great improvement in the state of health of the community: and being a particularly soft water, containing about one grain of solid inorganic matter per gallon, a saving in soap was effected, estimated at £36,000 per annum. The evidence with regard to the spread of certain diseases by impure water is contradictory and unsatisfactory. The connection has, however, been definitely established, among others, in the cases of malarial fevers, enteric fever, and cholera.

63. **Malarial Fever.**—There is a mass of evidence showing the injurious effect of drinking marsh water impregnated with organic matter. One of the strongest cases is that recorded by Boudin, and is known as the *Argo* case. There were 800 soldiers in good health transferred from Bona, in Algiers, to Marseilles in three vessels. Of these 680 men arrived safely without a sick man on board. In the *Argo* there were 120 men, of whom 13 died during the passage, and 98 were found on landing to be suffering from malarial fever. The soldiers on the *Argo* had been supplied with water from a marsh, while the other vessels had a good supply of pure water; all other conditions were exactly the same, and, as a further proof that impure water was the sole cause of the outbreak, it is stated that the crew of the *Argo*, of whom no one suffered, did not drink the marsh water, having a sufficient supply of pure water on board for their own use.

The number of cases of ague in a district has been materially lessened by digging wells, and using well, instead

of surface, water. Many cases are also quoted in which people have enjoyed exemption from ague by using other than marsh water. In one case, almost the only family in a district which escaped an outbreak was the only one using well water.

64. **Enteric Fever.**—The chief agent in the spread of typhoid or enteric fever is impure water. In a report of the Local Government Board, it was stated that of 142 epidemics of typhoid fever no less than 125 had been brought about by water containing organic impurities. There has been much discussion as to whether organic impurities alone can produce an outbreak of typhoid fever, or whether it is necessary that the specific germ should be introduced into the water: the balance of evidence is strongly in favour of the latter conclusion, though in some cases it has been found impossible to trace the source of the introduction of the typhoid poison. In the well-known Nunney case, the people in the village had been drinking the impure water for years, and no case of fever had occurred; but in May 1872 the excretion from a man suffering from the disease found its way into the stream, and between June and October of the same year there were 76 cases of typhoid fever out of a population of 832 persons.

Cases produced by water contamination develop more quickly than those produced by infected air. In several well authenticated cases, outbreaks of enteric fever have disappeared on ceasing to use an impure water-supply.

Outbreaks of typhoid fever have been caused by milk to which contaminated water has been added. Newsholme quotes a case in which eight children took milk which had been thus infected, three of them took it cold every day, and

the other five had it boiled. The three who took the cold milk were attacked with typhoid fever, the others escaped, showing that boiling destroyed the typhoid germs.

65. **Cholera.**—As in the case of typhoid fever, so with cholera, the evidence is overwhelming that impure water is an all-powerful agent in the spread of this terrible disease. A few cases will suffice to conclusively prove the connection. In the Yerrauda gaol case there were 24 cases of cholera in 5 days, with 8 deaths, out of 1,279 prisoners. Of these there were 134 prisoners employed as a road-gang, and among these 22 of the cases occurred. It was proved that these men had taken water from a river in which the clothes of two cholera patients had been washed. The other 1,145 prisoners, took the ordinary water-supply from a lake near Poonah, and among these there were only 2 cases of cholera, and these could be satisfactorily accounted for, both having come in contact with the cholera patients.

In the 1848 outbreak of cholera, the disease was universal in Glasgow. In 1854 the cases were almost entirely confined to the north side of the river, where the inhabitants used the river water, those on the south side having a pure water-supply. In 1866 the Loch Katrine supply was in general use, and though cases of cholera were introduced, it could get no hold on the city.

In the 1854 epidemic there were two water-supplies in the south of London, the Southwark Company and the Lambeth Company; the former was undoubtedly impure, while the latter contained very little organic matter. Although these companies covered the same district, supplying different houses in the same streets, the difference in the number of cases of cholera was most marked. Thus, among 266,516 people using the impure water-supply, there

were 4,093 cases, whereas there were only 461 cases among 173,748 people using the water from a comparatively pure source.

66. **Recognition of Impurity in Water.**—Waters from various sources have been classified by the Rivers Pollution Commissioners as follows :—

Wholesome	1. Spring water 2. Deep-well water 3. Upland surface water	Very palatable.
Suspicious	4. Stored rain-water 5. Surface water from cultivated land	Moderately palatable.
Dangerous	6. River water to which sewage gains access 7. Shallow-well water	Palatable.

Thus, it is seen that a suspicious or dangerous water may be quite palatable, and in some cases the sweet taste often associated with an impure water makes it more popular than water from a pure source. In some cases, the turbidity or smell is sufficient indication of its impurity; this is often the case with shallow-well water after rain, whereas, at other times, it is clear and sparkling, though absolutely unfit for drinking purposes. If a sample of such a water is corked up in a flask, and set aside in a warm place, it soon becomes turbid, and is found to be swarming with living vegetable organisms. A very impure water will also become turbid on warming, and will give off sulphuretted hydrogen, due to the decomposition of organic matter. In order to gain further information, the potassium permanganate test should be applied, and if necessary, a full analysis should be made by the ammonia-process. When sewage has found its way

into water it always contains large quantities of chlorides, which can be recognised by the dense white precipitate formed on the addition of a few drops of a solution of nitrate of silver to a sample of the water.

67. **Natural Purification of Water.**—Natural agencies are continually at work bringing about the purification of water. Sewage, consisting largely of solid particles, flows into a river; these particles are carried to a certain distance, depending upon the velocity of the stream; but sooner or later they are deposited in the bed of the river, and undergo changes by which they are made soluble, and then broken up into harmless gases. In a sluggish stream into which sewage is continually finding its way, the water may become so charged with organic matter, that the poisonous gases, given off by the putrefactive changes going on, may become a very serious danger to the health of people living on its banks.

The soluble organic matter is being continually destroyed by the oxygen present in the water, and if the amount of this gas is determined at various points in a river, it is found to vary with the amount of sewage contamination, being least where the organic matter is greatest. Starting with the normal quantity of oxygen before the river reaches a town, the amount of work it has to do on the entering sewage is so great that it cannot absorb from the atmosphere sufficient to keep the amount constant; and at certain points no free oxygen is found in the samples of water taken for examination. After passing the town, the work becomes less and less, and the amount absorbed is greater than that used up, so that once more it regains its normal quantity. Green plants in lakes and rivers play a most important part in this supply of oxygen. The carbonic acid is used as

food, the carbon being stored in the plant, and the oxygen set free in the water. Fish being entirely dependent on free oxygen for purposes of respiration, cannot live in waters so charged with impurity that there is an excessive demand upon this gas.

68. **Artificial Purification of Water.**—By distillation, as practised on board ship, perfectly pure water may be obtained, all inorganic and organic matters being left in the vessel in which the water is boiled. Distilled water is, however, very unpalatable, having a flat taste, due to the removal of dissolved gases. This may be remedied by pouring it through fine sieves, and so giving it an opportunity of taking up gases from the atmosphere.

By boiling water and then filtering it, the temporary hardness is removed, and a very large proportion of the living organisms present are destroyed. Those which escape are present in the form of spores; and, by leaving the water for some time so that these may develop, and then reboiling, the majority of these may be destroyed. Such water is practically safe for drinking purposes, but the objections against distilled water apply equally to this.

Filtration is the most useful and generally applicable means of purifying water. Agents employed for this purpose have, in most cases, a double action, mechanical and chemical. By the mechanical action the solid particles are removed by passing the water through a porous medium, such as sand and fine gravel, which retain bodies held in suspension.

In purifying water on the large scale, the water is first allowed to stand, to deposit the heavier particles, then passed through layers of sand and gravel, and then through beds of charcoal or spongy iron, by means of which the dissolved organic matter is wholly or partially destroyed.

On the small scale, the whole of the work, mechanical and chemical, is often thrown upon the charcoal, spongy iron, or whatever medium is used in the filter.

In all cases the filtering appliances must be thoroughly cleansed from time to time, or the filter may become a most prolific source of danger.

The requirements of a good filter are—

(1.) That every part of the filter shall be easily got at, for the purpose of cleansing or renewing the medium.

(2.) That the medium shall have a sufficient purifying power, and be present in sufficient quantity.

(3.) That the medium shall yield nothing to the water that may favour the growth of low forms of life.

(4.) That the purifying power be reasonably lasting.

(5.) That there shall be nothing in the construction of the filter itself that shall be capable of undergoing putrefaction, or of yielding metallic or other impurities to the water.

(6.) That the filtering material shall not be able to clog, and that the delivery of the water shall be reasonably rapid (Parkes' "Practical Hygiene").

69. **Carbon Filters.**—In all cases where carbon is used as a filtering medium, it should be thoroughly cleansed at regular intervals. This may be done by removing the carbon, and raising it to a low red heat out of contact with air, or boiling it with a strong solution of potassium permanganate, to which a small quantity of sulphuric acid has been added, and then washing with pure water. If neither of these methods can be adopted, a solution of permanganate with dilute acid should be poured through the filter until the colour of the solution is no longer affected, and then distilled water passed through for some time before

using. Carbon filters in which there is no provision made for cleaning should be studiously avoided, as, after a time, they become charged with organic matter, and the conditions rendered most favourable for the harbouring and propagation of vegetable organisms. Pure water passing through such a filter becomes polluted and unfit for drinking.

In Frankland's experiments with some impure water, he found that for the first twelve days all germs were removed by a charcoal filter, but after a month the filtered water contained more than five times as many germs as the unfiltered water.

Carbon blocks are often made of compressed animal charcoal: this contains large quantities of calcium phosphate, which acts as a nutrient for low forms of life, which it is one of the functions of the filter to remove. This may be partially removed by treatment with acids, and this is often done before the preparation of the blocks; but in all cases where this medium is used, the water should be filtered immediately before using, and should never be left in contact with the carbon.

Silicated carbon is prepared by mixing silica with the charcoal, and is a good filtering agent. By passing impure river water several times through this medium, Wanklyn has proved that it may be made as pure as deep spring water.

Manganous carbon is prepared by mixing with the charcoal large quantities of black oxide of manganese in the preparation of the blocks: by this means the oxidising power of the charcoal is largely increased.

The powerful action of a good carbon filter in removing organic matter may be shown, by taking an unfiltered and a filtered sample of the same water, adding sufficient per-

manganate to each to give them the same pink tint, and then letting them stand for twenty-four hours. At the end of this time the difference in colour will give a good indication of the value of the filter.

70. **Spongy Iron Filters.**—The use of spongy iron for purposes of filtration is of comparatively recent introduction. It is prepared by roasting hæmatite iron ore, and is similar in appearance to animal charcoal.

It has the power of decomposing water giving off hydrogen and taking up oxygen, which is used afterwards in breaking up the organic matter. The oxidising action is powerful, and filters made of this material retain their efficiency much longer than those in which carbon is used. Thus, unless the water is very impure, these filters do not require recharging or cleansing more frequently than once a year. If the old material is heated to redness it can be used again. An objection to spongy iron filters is that a certain amount of iron is taken up by the water, but this may be removed by passing it through sand or fine gravel.

These filters have the effect of removing a large proportion of the hardness of the water passing through them. For filtering water on the large scale, magnetic carbide of iron and polarite are much used. The great advantage in using these bodies is that, if the beds are well aerated occasionally, they will last for a very long period without necessity of renewal, though the beds of sand through which the water previously passes must be changed from time to time.

71. **Nature of Bacteria.**—Bacteria are very low forms of plant life. If a hay infusion is made and let stand for some time, and a few drops of the liquid are examined under a high power of a microscope, the water is found to

be swarming with various forms of bacteria. Some are seen to be quite passive, others dart across the field of view with great rapidity. These minute plants belong to the great fungus division—that is, they do not contain any chlorophyll, that green colouring matter which gives the plant possessing it the power of using the carbonic acid of the atmosphere in order to obtain its supply of carbon.

There are many varieties of bacteria, which may be roughly divided into groups, according as they are spherical, rod-like, or spiral in shape. Each plant consists of a mass of protoplasm surrounded by an ill-defined cell-wall. They vary considerably in size. Some of the rod-shaped varieties are from $\frac{1}{12000}$th to $\frac{1}{8000}$th of an inch in length, and average about $\frac{1}{80000}$th of an inch in diameter. It has been calculated that a space of one cubic millimetre would contain 250 millions of these plants, and that they would not weigh more than a milligram. In some cases they are provided with long processes or swimmerets by which locomotion is effected. Under certain conditions bacteria produce spores, in which form they can tide over unfavourable conditions, the spores being better able to withstand drought, and higher and lower temperatures, than the ordinary cells.

Two theories have been held with regard to the life-history of bacteria—

(1.) That there are very few true species, and that under varying conditions these may assume different forms.

(2.) That there are a great many species which remain the same in appearance under all conditions.

Under the first theory, the association of a particular kind of bacterium with a diseased tissue would be explained by the conditions favouring that particular form.

It is now known that a large number of species exist,

but that some forms which have been described are simply stages in the life-history of other forms.

Reproduction is nearly always effected by means of fission—that is, one bacterium divides into two. The rapidity with which these minute organisms multiply under favourable conditions, make them in some cases most dangerous enemies. In one case, it was found that within half-an-hour of division, the plants so produced divided again. Supposing the conditions to be favourable for such rapid multiplication, and that the whole of the plants produced survived, one bacterium would thus lead to the production of several billions of bacteria in twenty-four hours.

72. **Action of Bacteria.**—To understand the action of bacteria, it is well to consider first the action of a more highly organised fungus, the yeast plant, the action of which is well known. This plant, growing in the presence of sugar, has the power of breaking down this complex body into simpler ones, thus the molecule of sugar is resolved into molecules of alcohol and carbonic acid (p. 44). In some way the presence of this living plant renders the sugar molecules unstable, and they are resolved into more stable combinations.

In the same way, various forms of bacteria have the power of breaking down complex bodies in their immediate neighbourhood, the products depending upon the substance, the kind of bacterium, and the conditions under which they act. Thus, the bacterium commonly known as *mycoderma aceti* will, in the presence of oxygen, convert alcohol into acetic acid, thus producing the souring of wine; but if no free oxygen is present, it will convert sugar into alcohol and carbonic acid. Similarly, one of the colour-producing bacteria loses its particular power if

the temperature is raised, and produces other substances instead of colouring matters. *Bacterium lactis* acts upon the milk-sugar present in milk, and converts it into lactic acid, thus bringing about the souring of milk.

In these well-known processes bacteria have the power of bringing about decompositions of various kinds. Similarly, in the case of pathogenic or disease-producing bacteria, these plants, when established in the blood and tissues of the body, bring about important chemical changes, depending upon the kind of bacterium, and so produce the particular form of disease. The production of several diseases by the agency of bacteria has now been proved beyond all doubt. In cases of splenic fever, tuberculosis, erysipelas, diphtheria, typhoid fever, and many other diseases, the connection has been definitely established.

According to Koch, the following conditions must be fulfilled before a particular bacterium can be regarded as the cause of a disease :—

(1.) The organism must be present in the blood or diseased tissue of the man or animal suffering or dead from the disease.

(2.) The organism so found must be cultivated artificially, and freed from any kind of matter derived from the body from which it was taken.

(3.) After such cultivation, it must be introduced into the body of a healthy animal, and produce the disease in question.

(4.) The tissues of the animal so affected must contain the particular form of bacterium.

73. **Antiseptics.**—When milk is treated with salicylic acid, or preparations of borax and boracic acid, it may be kept any length of time without souring, because, in the

presence of these bodies, it is impossible for bacteria to carry on their work of converting milk sugar into lactic acid. In all putrefying wounds bacteria are the agents which produce the decomposition of the tissues, and the object of the antiseptic treatment of wounds is to render the conditions unfavourable for the activity of these organisms. This treatment has therefore the same object in view as the treatment of milk to prevent souring, and it is attained in the same way. Such bodies as carbolic acid, thymol, salicylic acid, perchloride of mercury, and many others have this power of preventing the destructive action of bacteria. They are not necessarily germicides, but their presence is, in some way, fatal to the activity of these organisms.

Lister, by his splendid work in this department, has done much to develop and perfect the antiseptic treatment of wounds in this country, in consequence of which the rate of mortality from difficult operations has decreased to a marvellous extent.

High and low temperatures are also fatal to the action of bacteria. Thus, in preserving meat or fruit in tins, the temperature is raised above the boiling point of water, so as to destroy the bacteria and also any spores present, the vessel is then securely sealed so as to prevent the entry of fresh organisms. Similarly, meat kept several degrees below the freezing point shows no tendency to decompose, because at this temperature it is impossible for bacteria to carry on their work.

74. **Bacteria in Air and Water.**—Nature has provided for our protection two most powerful disinfectants, pure air and water. The air of crowded rooms contains large quantities of bacteria, whereas in the pure air of the country

there are comparatively few, especially after rain, which carries them to the earth. It has been found impossible to detect the presence of any living micro-organisms in breezes coming from the sea, but in those blowing out from shore large numbers may be found.

In water tainted with organic matter, putrefactive bacteria will flourish, and generally the number of these bacteria may be said to vary with the amount of organic matter present, whereas pure water is fatal to their existence. Surface water generally contains great quantities of these organisms, because it comes from that part of the soil where bacteria are most active, and where there is most organic matter. Thus it brings with it not only bacteria but the food necessary for their life. In water, on the other hand, taken from deep sources, it is different, the soil through which this water has passed acts as a filter in the removal of bacteria and organic matter, as in the deeper strata of the soil practically no decomposition of organic matter is going on.

Thus, for drinking purposes, deep-well water is infinitely to be preferred to that from surface wells.

Pathogenic bacteria cannot be transferred from point to point by pure water, but in impure water not only can they be transferred, but the conditions are favourable for rapid multiplication.

75. **Importance of Bacteria in Nature.**—A most important function of bacteria is to render organic matter available for plant food, by converting it into inorganic combinations. The humus, or decaying organic matter of the soil, cannot be used until it is resolved into such bodies as carbonic acid, ammonia, and available salts of nitric and phosphoric acids. The green plant converts inorganic into

organic matter: by the action of bacteria this work is undone, and the material again prepared for the highly-organised plant. It is the same with animal organic matter; bacteria bring about decomposition, and so the materials again take their place in the circulation of matter. As was truly stated by Duclaux, "Whenever and wherever there is decomposition of organic matter, whether it be the case of a herb or an oak, of a worm or a whale, the work is exclusively done by infinitely small organisms. They are the important, almost the only, agents of universal hygiene: they clear away more quickly than the dogs of Constantinople or the wild beasts of the desert the remains of all that has had life: they protect the living against the dead."

CHAPTER VIII.

DIGESTION.

76. **Object of Digestion.**—In the human body chemical changes are continually taking place, complex substances are ever being broken up into simple ones, setting free stores of energy, some of which is utilised in various forms of work; but the majority of it is dissipated as heat, by which the temperature of the body is maintained. In order to supply the loss caused by this destruction of the materials of which the body is composed, food must be introduced from time to time.

Food may be defined as *that which, when introduced into the body, can repair its structure and make it capable of doing work.* The great proportion of the food taken is insoluble, and incapable of passing through an animal membrane, and the whole object of digestion is to bring about various chemical changes which make this passage possible, as it is only when the food has passed through membranes and joined the blood stream that it can restore the waste continually going on. Large quantities of valuable food may be consumed, but unless the digestive system is in good working order, and able to effect the necessary transformations, the person taking it may die of starvation.

If the various constituents of a good dinner were pounded up together in a mortar, and then introduced into

a bladder, and the closed bladder placed in a vessel of water for some time, it would be found that very little of the contents would pass out into the surrounding water. If, however, preparations of the digestive secretions were introduced in order, at intervals, and well mixed with the food, the water in the vessel would be found to contain large quantities of different kinds of food material. In this experiment, the bladder represents the alimentary canal, the surrounding water the blood stream, and the changes going on within the bladder the process of digestion.

77. **The Digestive Apparatus.**—When food is taken into the mouth, it is ground between the teeth, by which particle is separated from particle, and a large surface exposed to the action of the various secretions. This is termed mastication, and the importance of thoroughly carrying out this preliminary treatment of the food, and thus diminishing the work in its subsequent treatment, cannot be over-estimated. While this is going on, the food becomes saturated with saliva, an alkaline fluid which is poured into the mouth by the numerous small buccal glands situated in the lining mucous membrane, and three pairs of salivary glands,—the parotid, submaxillary, and sublingual,—which communicate with the mouth by means of tubes or ducts.

The food is then rolled into a bolus, passed through the back of the mouth into the pharynx, and then into a short tube, the gullet or œsophagus, which quickly conveys it into the cardiac end of the stomach (Fig. 24). There the food becomes acid, due to the action of the gastric juice, a secretion poured on to the food by a number of tube-like glands situated in the walls of the stomach. While the food is in the stomach it is subjected to a churning motion, the food

passing round and round until it is sufficiently reduced to a liquid state to pass through the pyloric end of the stomach into the small intestine. The time it is retained

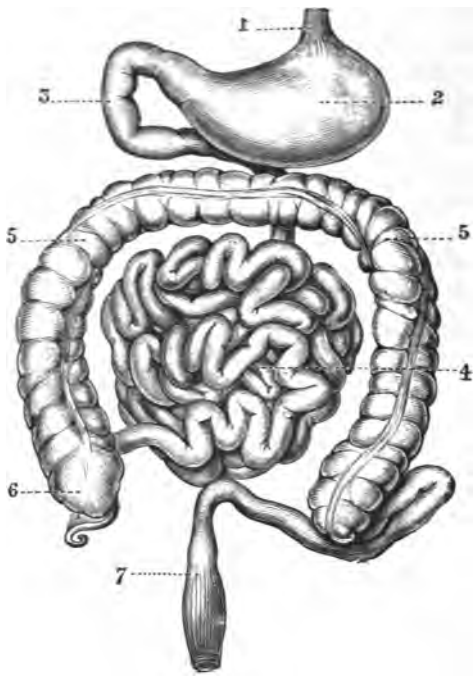


Fig. 24.

1, the gullet; 2, the stomach; 3 and 4, the small intestine; 5, the large intestine; 6, the cæcum; 7, the rectum.

in the stomach varies on average from one to five hours, depending on the digestibility and state of mastication of the food.

On passing into the small intestine, the food once more becomes alkaline, due to the action of the bile, which is

secreted by the liver, stored in the gall-bladder, and poured into the intestine by the bile duct. Directly the acidity of the food has thus been destroyed by the bile, it is acted upon by the pancreatic juice, a most important secretion from the pancreas, which is brought to the intestine by the pancreatic duct at the same point as the bile duct enters.

By the action of these various secretions a large proportion of the food is made soluble, and capable of passing through a membrane. It then joins the blood stream in a manner to be described later.

78. **Classes of Food-Stuffs.**—Man requires very highly organised food, some of the food-stuffs being similar in composition to substances which form a large proportion of his own body. He has not the power, which the plant possesses, of building up organic matter from inorganic materials.

Protoplasm consists of the elements carbon, hydrogen, oxygen, and nitrogen, and small quantities of sulphur and phosphorus, and if the body is to be maintained in health these elements must be taken in an easily digestible form. For this purpose four classes of food-stuffs are used, proteids, fats, carbohydrates, and mineral substances.

The name proteid is given to an important class of organic bodies, which contain carbon, hydrogen, oxygen, and nitrogen, together with sulphur and phosphorus. They contain about 50 per cent. of carbon, and 15 per cent. of nitrogen. Various forms of these bodies are found in nearly all ordinary articles of diet; the myosin of muscle, the gluten of flour, the casein of milk, the albumen of eggs, and the fibrin of blood, are common examples. Proteids are the only common food-stuffs which contain nitrogen, and should therefore receive special attention, as large quan-

tities of this element are continually required to restore the nitrogenous waste of the body.

Fats are the glycerine salts of such organic acids as stearic, oleic, and palmitic, the sodium salts of which form the various soaps. Fats contain roughly 80 per cent. of carbon, 10 per cent. of oxygen, and 10 per cent. of hydrogen. The ordinary meat-fats and animal and vegetable oils are examples of this class.

The carbohydrates also consist only of carbon, hydrogen, and oxygen, but may be easily distinguished from the fats. They contain about 40 per cent. of carbon, and the hydrogen and oxygen are present, as the name suggests, in the proportion in which they exist in water. Such compounds as cane sugar ($C_{12}H_{22}O_{11}$), milk-sugar ($C_{12}H_{22}O_{11}$), glucose ($C_6H_{12}O_6$), starch ($C_6H_{10}O_5$), and cellulose ($C_6H_{10}O_5$), are members of this group.

Mineral matters, such as common salt, phosphates, lime and potassium salts, and water, play an important, though often indirect, part in the processes of digestion. They are necessary in influencing the important chemical changes, or metabolism, going on in the body. The beneficial action of fruit and fresh vegetables as articles of diet is, in many cases, largely due to the presence of these compounds. Certain forms of scurvy and other derangements may result from an insufficient supply of this class of food-stuffs, whereas an excess may act injuriously.

A dog fed on nothing but Liebig's extract dies sooner than a dog not fed at all, on account of the potash salts of the extract exerting their deleterious influence in the absence of the food, whose metabolism their function is to direct (Foster).

79. **Action of Saliva.**—The saliva, as we have seen, is

poured into the mouth from glands, which have the power of manufacturing from the blood a substance which has an important action on one class of food-stuffs; these are termed the salivary glands. Similarly, the gastric glands, the liver, and the pancreas, manufacture substances which are widely different from saliva, and which all play important parts in the process of digestion. Thus the food, in passing through the alimentary tract, is subjected to the action of various secretions, all prepared from a common source—the blood—by the active cells of various glands.

Saliva contains a special ferment, ptyalin, which has the power of converting starch into sugars, principally dextrose and maltose. It is termed a hydrolytic ferment, because the action consists in the addition of water, thus—

$$\underset{\text{Starch.}}{C_6H_{10}O_5} + H_2O = \underset{\text{Dextrose.}}{C_6H_{12}O_6}$$

$$\underset{\text{Starch.}}{2C_6H_{10}O_5} + H_2O = \underset{\text{Maltose.}}{C_{12}H_{22}O_{11}}$$

In these changes an intermediate body, dextrin, is formed; but, by the continued action of the saliva, the whole of the dextrin is converted into sugar. The equations given above only represent the most important chemical changes brought about by the saliva.

By the action of bacteria we have seen that similar chemical changes may be produced. These are spoken of as organised ferments, whereas the ferments associated with the saliva, gastric juice, and pancreatic juice are not living organisms, and are termed unorganised ferments. The action of saliva may be illustrated by putting some boiled starch solution in contact with saliva for a short time, and then testing for the presence of starch and sugar. The best test for starch is the blue colour given

when a few drops of a solution of iodine are added to a liquid containing starch in solution. In order to test for sugar, the solution is boiled with a small quantity of Fehling's solution, which is prepared by adding caustic potash to a solution of sulphate of copper, and dissolving the precipitate formed by Rochelle's salt. If sugar is present the blue colour is destroyed, and an orange colour produced by the formation of cuprous oxide. In this experiment, if the saliva has completed its work, it will be found that all the starch has disappeared, and sugar has been produced.

Saliva is alkaline, and it is found that it cannot carry on its work in an acid medium; thus, if, in the experiment performed, an acid had been added during the conversion of starch into sugar, the action would have ceased immediately. Therefore, when the food passes into the stomach, the action of the saliva ceases, because it is made acid by the gastric juice.

The saliva has no action upon fats or proteids. It is secreted in large quantities, two to three pints being given out in twenty-four hours: the presence of food in the mouth causes an active flow, and, in the case of a hungry man, a savoury smell, or the sight of food, is quite sufficient to produce the same result, bringing about the well-known sensation of making the mouth water.

80. **Action of Gastric Juice.**—When the food reaches the stomach, it is soon rendered acid by the action of the gastric juice, which is poured out in large quantities. The flow of gastric juice continues until the food is converted into a semi-liquid form, and passes through the pyloric end of the stomach into the small intestine. This secretion has no action upon the carbohydrates. Its action upon

the fats consists chiefly in dissolving the proteid envelopes which surround the particles, and so setting free the fat, which, at the temperature of the stomach, melts, and mixes intimately with the other food-stuffs. In addition to this, it has a slight emulsifying action—that is, it breaks up some of the fat globules into much finer particles.

The all-important action of the gastric juice is the conversion of insoluble proteids into soluble proteids, which are called peptones. Some of the proteids are converted into parapeptones, which are probably intermediate in character between proteids and peptones. The essential principle of gastric juice is pepsin, which can only perform its functions in the presence of an acid, which, normally, is dilute hydrochloric. If some finely-divided meat is placed in a vessel with water and a preparation of gastric juice, at ordinary temperatures, the meat slowly dissolves, and, if the water is tested, it is found to contain large quantities of soluble proteids. The test applied is heating with nitric acid, when a yellow colour is produced, which becomes orange on making the solution alkaline with ammonia.

81. **Action of Bile.**—Much doubt exists as to the exact function of the bile. It has no action on proteids or carbohydrates. Its first action is to neutralise the acidity of the food entering the small intestine, and so prepare it for the action of the pancreatic juice, and it appears to have a slight effect upon the fats producing emulsification. Thus, if a thick oil is shaken up with bile, it will pass through a membrane, especially if the membrane is first moistened with bile, though previous to this treatment it shows no tendency to do so. In conjunction with pancreatic juice it acts much more quickly and efficiently as an emulsifying agent.

82. **Action of Pancreatic Juice.**—Before the food is subjected to the action of the pancreatic juice, the carbohydrates, proteids, and fats have been acted upon by the saliva, gastric juice, and bile respectively, but the action in each case has been a partial one, and the pancreatic juice completes or nearly completes the work of digestion in each class of food-stuffs.

The amount secreted by the pancreas in twenty-four hours is on average about half-a-pint. It is alkaline in reaction, due to the presence of sodium carbonate, which is as important an ally as hydrochloric acid in the case of gastric juice. It has no power of carrying on either of its functions in an acid medium. There are probably three ferments present in this secretion.

The action on carbohydrates is similar in every way to the action of saliva, starch being converted into sugar. It has a double action on fats. It reacts with them to form soaps, setting free the glycerine, and it also has a powerful emulsifying action which is probably aided materially by the presence of the soaps produced.

Its action on proteids is due to the ferment trypsin; peptones are produced, but the action does not stop here, as in the case of gastric juice. Some of the peptones are further acted upon and broken down into crystalline bodies, such as leucin and tyrosin, which are not proteid in nature.

The experiments performed with saliva, gastric juice, and bile may all be repeated with pancreatic juice with similar results.

There are other secretions which play their part in the digestion of the food after it passes beyond the action of the pancreatic juice, but these are of comparatively little importance.

83. **The Passage of Food into the Blood.**—In order that soluble food may be of service in supplying the varying needs of the body, it must in some way reach the blood stream, and, by means of the circulation, be carried to the points where it is required. There are two ways in which this passage from the alimentary tract to the blood is effected. In the walls of the various parts of the tract there are numerous blood capillaries which join together and form veins, which, in their turn, unite and form part of the portal system, by which the blood is carried to the liver. These capillaries, as we have seen, have exceedingly thin walls, and the conditions are in every way favourable for the passage of soluble food. Sugar and peptones in this way join the blood stream, but the course taken by the fats is different.

In the small intestine there are numerous little hair-like projections so closely packed together that a threepenny piece would cover five hundred of them. These structures are termed villi. Figure 25 represents three highly magnified villi, and shows their internal structure. The covering represented in the figure by dotted lines consists of epithelial cells. Internal to this there is a loose tissue in which there are numerous blood vessels. In these villi, arteries break up into capillaries, and these again join up to form veins (*v*). These networks of blood vessels enclose a central hollow portion, the lacteals (*l*), which run together at the base, forming a lymphatic plexus. The liquid food passes through the epithelial layer, the peptones and sugars pass into the capillaries and the fats into the lacteals. By means of longitudinal contractions, the contents of the lacteals are forced into the larger spaces in the lymphatic plexus. These irregular vessels are provided with valves,

so that the contents do not pass back into the lacteals when the contraction ceases; the food is conveyed by the lymphatics to the root of the neck, and there poured into the blood stream at the junction of the jugular and subclavian veins on the left side. Thus, directly or indirectly,

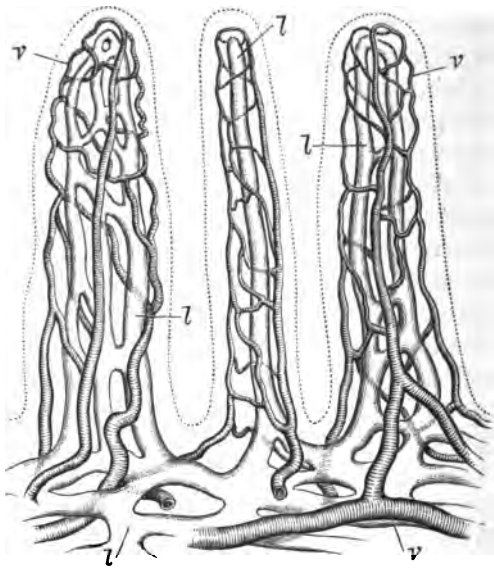


Fig. 25.

sooner or later, the whole of the digested food finds its way into the blood stream.

84. **The Daily Loss.**—Very little is known about the chemical changes which take place in the blood and tissues, which result in the formation and restoration of the various structures in the body from the soluble food taken into the blood. Similarly, we have little informa-

tion with regard to the destructive changes going on by which carbonic acid, urea, and water are produced, during which processes large quantities of heat are evolved. The initial and final products are known, but the intermediate stages cannot be accurately followed. It was thought formerly that much of the material taken into the body was directly oxidised in the blood, which was regarded as the seat of the formation of carbonic acid; but it is now known that these important changes take place in the tissues themselves, the oxygen taken into the blood as it passes through the capillaries of the lungs being given up to the tissues, where it produces instability in the bodies which undergo destructive metabolism.

The amount of carbon given off as carbonic acid, and the amount of nitrogen given off as urea and uric acid, can be calculated, and thus the daily loss of carbon and nitrogen in the tissues can be determined. It has been found that a fully-grown man, taking a fair amount of exercise, gives off on average about 4000 grains of carbon, and 300 grains of nitrogen in twenty-four hours, and if his body is to be maintained in health, sufficient food must be taken in a digestible form to make good this loss.

In deciding upon the details of diet for this purpose, the relation of carbon to nitrogen, which is about 13 to 1, must be borne in mind, and also the different actions of the digestive secretions, in order to avoid waste of material, and also to avoid overburdening a particular part of the digestive system.

85. **Necessity for a Mixed Diet.**—It is evident from the amount of carbon and nitrogen which leaves the body daily as waste products, that a mixture of food-stuffs is the most economical form of diet. If an animal is fed on carbo-

hydrates or fats, or mixtures of these substances, it soon dies of nitrogen starvation. On the other hand, if it is fed on proteids alone, such as albumen, fibrin, myosin, &c., there is a great waste of nitrogenous material. Proteids contain about 50 per cent. of carbon, and 15 per cent. of nitrogen. Therefore, in order to obtain 4000 grains of carbon 8000 grains of proteid matter will be required; but this amount of nitrogenous food will yield 1200 grains of nitrogen, of which only 300 grains are required to supply the daily requirements. Thus, there will be a daily waste of 900 grains of nitrogen, and, moreover, the secretions interested in the digestion of starches and fats will be standing idle, and those concerned in the digestion of proteids will be over-worked.

If 2000 grains of proteids and 7500 grains of carbohydrates (40 per cent. carbon) are taken, there will be practically no waste, the proteids yielding 1000 grains of carbon and 300 grains of nitrogen, and the carbohydrates 3000 grains of carbon. The place of the carbohydrates may be taken by fats, in which case only 3750 grains will be required, since these bodies contain 80 per cent. of carbon. It is better, however, to supply the 3000 grains of carbon by mixtures of fats and carbohydrates, as there is then an equal distribution of the work of digestion among the various secretions. In these calculations no allowance is made for waste, and the substances are taken as being chemically pure and dry.

The most common articles of food are mixtures of foodstuffs: thus bread contains carbohydrates and proteids, and milk contains, in excellent proportions, fats, carbohydrates, and proteids.

Where people are compelled to live on one particular

kind of food it is always unsatisfactory, and, from a physiological standpoint, wasteful: this is well shown in countries where potatoes or rice form, for a portion of the people, the staple diet. People living on these kinds of food must obtain the requisite quantity of nitrogen if they are to remain in a healthy condition. This necessitates taking far more carbon than is necessary, because in these foods the proportion of nitrogen is exceedingly small: the result is that the digestive system is overloaded, and much more work is thrown on certain portions than would be the case with a mixed diet.

86. **The Effect of Cooking on Digestibility.**—Man is the only animal that cooks his food. The object of this is to make it more palatable and easy of digestion. Thus raw meat requires far more time for complete digestion than cooked meat, and the crust of bread is more digestible than the interior of the loaf. In the case of bread, chemical changes go in the direction of the conversion of starch into sugar, so that the work of the saliva and pancreatic juice is lessened. People may eat dry toast with impunity to whom soft bread would be difficult of digestion. This is not only because the cooking operations have been carried further in one case than the other, but also because the dry particles may be more readily separated from each other, and so give a larger surface for the action of the secretions.

The temperature of cooking is of the greatest importance, as from the point that proteïds coagulate, the substances become less and less soluble as the temperature is raised. If a clear solution of albumen is heated up to 160° F. solid particles appear, and soon the solution becomes quite opaque. If these particles are collected and

heated to a much higher temperature, a very hard substance known as egg-cement is produced, which would be impossible of digestion, whereas at the point of coagulation the albumen is very digestible. The difference in digestibility of albumen is well shown by the times taken for complete digestion of eggs under different conditions.

Raw whipped eggs . .	require	$1\frac{1}{2}$ hours.
Properly cooked eggs .	„	$2\frac{1}{4}$ hours.
Hard boiled eggs . .	„	$3\frac{1}{2}$ hours.

Thus, in cooking operations, after immersing a joint of meat in boiling water to coagulate the proteids on the outside, so as to prevent the valuable soluble materials escaping, it is well to lower the temperature in order to secure greater digestibility. At 180° F. all the proteids will coagulate, but longer time is required for cooking than if kept at the boiling point.

CHAPTER IX.

BREAD AND MEAT AS ARTICLES OF DIET.

87. **Composition of Bread.**—If some flour is placed in a muslin bag and well washed with a stream of water, the water carries through the meshes of the muslin large quantities of starch grains which have a characteristic appearance under the microscope. A sticky substance is left in the bag, which is found on examination to be a mixture of more or less pure proteid substances, to which the name gluten is given. Flour may thus be readily separated into carbohydrates and proteids. By appropriate methods a small quantity of fat may be separated, and if a sample of flour is heated to a temperature at which all the organic matter is burnt away, a white residue is left, which on analysis is found to contain such important bodies as potassium, sodium, and magnesium salts, phosphates in large quantities, and a small proportion of sulphates.

In the manufacture of bread from flour, very important chemical changes go on. A portion of the proteids is made more soluble, the starch grains are ruptured, and some of the starch is converted into dextrin and sugar.

Bread is a very near approach to an ideal food. It contains all the classes of food-stuffs, and is of itself able to maintain life for a considerable time. The proportion of carbon to nitrogen is, however, about 20 to 1 instead of 13 to 1 as required, and therefore it should be taken with

food containing a large proportion of nitrogen, such as meat, eggs, &c. The small percentage of fat, compared with the amount of carbohydrates, also militates against it as a complete diet.

Composition of white bread of average quality—

Water, ...	40 per cent.
Proteids, . . .	8 „
Fats, ...	1·5 „
Carbohydrates, . .	49·2 „
Salts, ...	1·3 „
	100

Experience teaches that the crust of bread is more digestible than the softer portions. This is largely due to the mechanical difficulty in thoroughly masticating the latter, but undoubtedly it is also due to the chemical operations, in the direction of greater digestibility of the constituents, having been carried further. The question of the relative nutritive values of crust and crumb is a debated one, but analyses (made by Barral) point strongly in favour of the crust.

	Crust.	Crumb.
Water, ...	17·15	44·45
Insoluble nitrogenous substances (gluten, &c.), . .	7·30	5·92
Soluble nitrogenous substances,	5·70	0·75
Soluble carbohydrates (dextrin, sugar, &c.), ...	4·88	3·79
Starch, ...	62·58	43·55
Fats, ...	1·18	0·70
Mineral substances, . . .	1·21	0·84
	100·00	100·00

Bread becomes more easy of digestion on keeping, due to some molecular change which goes on, and which enables the separation in mastication to be effected more readily. It was thought that this difference between old and new bread was due to a loss of water. Boussingault, however, proved by his experiments that bread kept for six days lost only 1 per cent. of its water, and that when stale bread is placed in an oven, at a temperature of about 300° F., for an hour, though it may lose $3\frac{1}{2}$ per cent. of its water, it regains the qualities of new bread.

88. **Varieties of Bread.**—Ordinary white bread is made from flour obtained from the interior of the wheat grain, the whole of the outer portion being removed. Analyses prove that this outer portion contains a much larger proportion of nitrogenous matter, phosphates, and fats than the interior, but it also contains in the outer layers of the shell a quantity of silicious matter which is very difficult of digestion. Therefore the covering of the grain contains, among others, just those elements in excess which are not present in sufficient quantity in white bread to raise it to the standard of a perfect food. Numerous attempts have been made to make use of these valuable constituents.

Ordinary brown bread is made from flour from which the bran has not been separated. This undoubtedly contains more nutritive material than white bread, and, where it can be digested without difficulty, is much to be preferred. In many cases, however, the presence of sharp particles, due to the silicious matter, produces irritation of the mucous membrane of the stomach and intestines. This objection has largely been met by the removal of the outer envelopes of the grain containing most of the silicious matter, and grinding the remainder of the grain between

steel rollers so as to reduce the whole to a fine powder. Bread made from this flour is known as wheat-meal bread, or decorticated whole-meal bread, and has much to recommend it.

89. **Methods of Raising Bread.**—If water is thoroughly mixed with flour, and the dough so formed is baked, unleavened bread is produced, which is as unpalatable as it is difficult of digestion. The gluten, which is such an important constituent, by its cohesiveness, renders it most difficult to separate, and thus expose to the action of the digestive secretions. It has been a very important problem from the earliest times to find good means of leavening bread. At present there are three processes in general use, in all of which carbonic acid gas is used to separate particle from particle, and thus increase the volume of the bread. Thus, in a properly prepared loaf, there are about 3 cubic inches of air spaces to 1 cubic inch of nutritive material.

In the method in most general use the yeast plant is used to carry on its work of fermentation. The first chemical change effected is the conversion of some of the starch present into sugar. The sugar is then broken down into molecules of alcohol and carbonic acid (p 44). At the temperature of baking, the alcohol, which has a lower boiling point than water, is all driven off, and the yeast cells are destroyed, so that no further action goes on. In order that this method may be successful, the yeast must be fresh, and thoroughly distributed over the dough, otherwise large evolutions of gas take place in certain regions, and in other portions no leavening action takes place. When properly mixed, however, every little cell or group of cells starts its manufacture of carbonic acid, and, as the gas is produced, adjacent particles are forced apart. While the raising is

going on, the dough is kept at a temperature favourable for the activity of the yeast.

The Dauglish method, by which aerated bread is produced, is a purely mechanical one. Water charged with carbonic acid under a pressure of 150 to 200 lbs. to the square inch, is mixed with flour in strong iron vessels. After thoroughly kneading the mixture, the pressure is removed, and the carbonic acid, in attempting to escape, forces the particles asunder. This expansion is further increased in the oven, to allow for which special arrangements are made by which the heating first takes place from below, and after the swelling has practically ceased, heat is applied above, and the upper crust is formed. There are many points in favour of this method of raising bread. The mixing is very perfect, and is much more cleanly than the former method, in which hands, and often feet, are used in effecting it. It is also urged that there is no waste of valuable material, as when starch is used for the production of carbonic acid. On the other hand, the fermentative changes, which in this method are absent, lead to the production of bodies which are very easily digested. It is possible, however, that by the more perfect mixing in the preparation of aerated bread this may be more than counterbalanced.

Baking powders are also largely used for the leavening of bread. In all these an acid substance is mixed with a carbonate, which leads to the evolution of carbonic acid. Bicarbonate of soda is generally used with hydrochloric or tartaric acid. Here evil effects may result from the impurity of the acid, or from the powder being unevenly distributed. Moreover, the continual action of tartrate of soda, produced by the action of tartaric acid on

bicarbonate of soda, is, in many cases, injurious. The best form of baking powder is unquestionably a mixture of bicarbonate of soda and the acid phosphates of lime or potash. This, on the addition of water, yields carbonic acid, and the salts produced are serviceable as food.

90. **Adulteration of Bread, and Methods of Detection.**—The addition of mashed potatoes to dough where fermentation is to be used as the method of raising, can hardly be spoken of as adulteration. It is done quite openly, and serves the useful function of assisting the fermentative changes.

The addition of rice flour to ordinary flour is simply for the purpose of reducing the cost, and produces bread of inferior quality. It is almost impossible to detect this adulteration in bread, but in flour it is easily detected by the different appearance of the starch grains under the microscope.

The adulteration of cheap flours with sulphate of lime is very rarely resorted to in the present day. The presence of such a body in bread may be detected by the large amount of ash obtained, and by individual tests for this compound.

The addition of salts of copper to improve the colour of the bread was formerly a favourite method of adulteration in Belgium and other places. It may readily be detected by treating a sample of the suspected bread with acetic acid and a solution of yellow prussiate of potash, when a chocolate colour is produced if any copper is present.

Practically, the only important adulterant in present use is alum, which is added for the purpose of improving the colour of the bread, probably by increasing its porosity, and so enabling the baker to use an inferior flour. Authorities

differ as to the exact effect upon health of taking bread continually which contains alum, but it is generally agreed that it is injurious. The best method of detection is to place a piece of bread in a fresh solution of logwood (prepared by the action of alcohol on logwood chips) to which a small quantity of carbonate of ammonia has been added. The piece of bread is then taken out and dried. If it contains no alum the colour will be a brownish red, but if it contains this substance, it will have a lavender, or, if in excess, a dark-blue colour.

91. **Composition of Meat.**—The most important points of difference between the composition of meat and bread are—(1) meat contains no carbohydrates, whereas bread contains about 50 per cent.; (2) the percentage of fat, even in the leanest meat, is greater than in bread; and (3) meat contains about three times as much proteid matter as bread.

In the following table (abstracted from Parkes) of the composition of different kinds of meat, A represents uncooked beefsteak of best quality, with very little fat; B, uncooked meat from fattened cattle; and C, roast meat, no dripping being lost:—

	A	B	C
Water, . .	74·4	63·3	54
Proteids, . .	20·5	14	27·6
Fats, ...	3·5	19	15·45
Salts, . .	1·6	3·7	2·95
	100·0	100·0	100·00

Knowing the chemical composition of proteids and fats, the proportion of carbon to nitrogen in each case can be calculated; thus—in A the proportion is about 4 to 1, in B

10 to 1, in C 6 to 1, whereas, in an ideal food, the proportion should be 13 to 1. Therefore, if meat, even if abnormally fat, as in B, is taken alone, there must be very considerable nitrogenous waste. In bread, as we have seen, the proportion of carbon to nitrogen is about 20 to 1; therefore, by a mixed diet of bread and meat, not only can the carbon and nitrogen be taken in the required proportions, but there is also a fair division of labour among the digestive secretions, since all the classes of food-stuffs are properly represented.

92. **Methods of Cooking.**—The method of cooking meat materially affects its composition. Valuable extracts may be obtained by submitting finely-divided meat to a temperature of about 140° F.: the important extractives and soluble proteids pass into solution, together with some of the inorganic salts. On raising the temperature further, the proteids begin to coagulate, and this continues until the temperature reaches 180° F. If the scum so formed is removed, the most nutritious portion of the extract is lost. To obtain a broth of maximum nutritive value the temperature should not pass beyond 150° F. or 160° F.

Parkes states that in this way a pint of beef broth may contain about 150 grains of organic matter, and 90 grains of salts, consisting chiefly of chlorides and phosphates. In the production of such extracts as Liebig's, the coagulated proteids are removed, so that these preparations have little nutritive value, but they contain the valuable soluble extractives and salts from a large quantity of meat, which act as stimulants, and may be taken with advantage with more nutritive foods.

In boiling meat there is generally a loss of from 20 to 30 per cent. From an economical standpoint stewing is

the ideal method of cooking. A large surface is exposed to the action of the water, and practically none of the nutritive matter is wasted,—the loss, which is rarely more than 20 per cent., being almost entirely due to the loss of water.

In roasting, as in boiling, after coagulation of the external proteids to prevent excessive loss, the temperature may be lowered with advantage, provided the temperature of the interior of the joint does not fall below 160° F. If the outside is subjected to too high a temperature, the external fats are decomposed, and products formed which are unpalatable and indigestible.

Reference has already been made to the effect of the method of cooking upon digestibility. In cases, however, where injurious parasites may be introduced into the body, as in veal and pork, or where any doubt exists as to the possibility of the meat being tainted, the temperature throughout should be raised to the boiling point of water in order to effect the destruction of any living organisms.

93. **Comparison of Animal and Vegetable Food.**—Apart from the difference in composition of animal and vegetable foods (the abundance of proteid and fat in the former, and the large proportion of starch in the latter), there are differences in nutritive value and digestibility.

The herb-eating animal acts as a middleman between the plant and man, manufacturing from vegetable proteids animal proteids, which are more easily digested, and more nutritious. Very little is known of the chemical constitution of these bodies, but analyses prove that the proteids from animal and vegetable sources have almost exactly the same proportions of the various constituents. Thus, taking two animal proteids—myosin, the chief constituent of muscle, and egg albumen,—and two vegetable proteids,

such as vegetable albumen, which is of common occurrence in vegetable juices, and legumin or vegetable casein, found in large quantities in peas, beans, &c., we find them to be of almost identical composition—

	C	H	N	O	S
Myosin, . .	53·87	7·21	15·57	22·03	1·21
Egg Albumen, .	53·40	7·00	15·70	22·40	1·60
Vegetable Albumen,	53·06	7·33	16·58	21·93	1·10
Legumin, . .	51·48	7·02	18·22	22·88	0·40

The difference in these foods physiologically is, however, very marked, a much larger proportion of the animal proteids being converted into peptones, and so passing into the blood stream. The fact that these bodies in the vegetable organism are protected largely by cell walls of cellulose, which is very indigestible, would partly account for such a large proportion escaping digestion. Mutton takes less time for complete digestion than bread, and an egg is digested more quickly than a potato. It appears from experiments made by Hofmann that the difference between animal and vegetable food is much more marked in the case of proteids than in that of carbohydrates.

Weight of Food.	Vegetable.		Animal.	
	Digested.	Undigested.	Digested.	Undigested.
Of 100 parts of Solids,	75·5	24·5	86·9	13·1
,, ,, Albumens,	46·6	53·4	81·2	18·8
,, ,, Carbohydrates,	90·3	9·7	96·9	3·1

Sheep and oxen have stomachs specially adapted for digesting foods containing much fibre. They thus play an important part in preparing animal proteids from vegetable food. Horses have not this power to the same extent—*e.g.*, they digest about 12 per cent. less of the total organic matter of grass-hay than sheep.

Quite apart from the difference in digestibility, it appears that vegetable foods are slower in their action than animal foods in restoring the waste going on in the body.

94. **Flesh Formers and Body-Warmers.**—Liebig classified foods into two main divisions, the flesh-formers and body-warmers. Nitrogen is an essential constituent of all important tissues; fats and starches contain large quantities of carbon, but proteids are the only food-stuffs which contain nitrogen. He concluded that proteids alone were interested in the formation of the muscular tissues, and that fats and starches, by oxidation to carbonic acid and water, maintained the warmth of the body. It is found, however, that this hard and fast division of the functions of the different food-stuffs will not hold. Proteids, by their decomposition, set free stores of energy, and fats and carbohydrates take their part in building up the tissues of the body.

The following table by Professor Frankland shows the amount of heat given out by 10 grains of different foods during their complete combustion in the body, in terms of the number of pounds of water which would be raised through 1° F.:—

10 grains of	dry flesh	=	11·23
„ „	„ albumen	=	10·94
„ „	lump sugar	=	8·61
„ „	arrowroot	=	10·06
„ „	butter	=	18·68
„ „	beef-fat	=	23·32

Thus it appears that proteids give out large quantities of heat, and carbohydrates give out about half as much as fats. Thus we find, in very cold countries, fats are taken in preference to carbohydrates, but in hot countries carbohydrates are more popular.

The action of one class of food is modified by the presence of another, and transformations from one kind to another take place within the body.

Proteids exercise a great influence on the metabolism of the body, and control its energies. They also are used up in restoring the waste going on in the tissues, and, under some conditions, lead to the production of fat by breaking up into nitrogenous and non-nitrogenous compounds. It is the only class of food-stuffs capable in itself of supporting life for any length of time.

If proteids alone are taken in large quantities, destructive metabolism is so active that the body loses in weight, as in the treatment for the reduction of corpulency; whereas, if a smaller quantity of proteids is taken together with some fat, metabolism is not so active, and the body may put on weight. The fat in some way shields or checks the action of the proteid. During active exercise, however, the stored fat undergoes oxidation, and thus acts as a store of energy for the body, whereas nitrogenous metabolism is very little affected. The increase of carbonic acid given out during violent exercise is almost entirely due to the oxidation of non-nitrogenous material.

Carbohydrates undergo oxidation in the body more readily than fats or proteids, and thus indirectly assist in the storage of these bodies. They are found in the form of glycogen in the liver, but they are not stored as carbohydrates in the tissues of the body. Thus the addition of carbohydrates to a diet of proteids and fats materially assists in an increase of weight, as they shield these substances from destructive metabolism.

Under certain conditions carbohydrates are converted into fats, though the chemistry of these changes is un-

known. Lawes and Gilbert concluded from their experiments that 40 per cent. of the fat in some pigs was derived from this source.

It will, therefore, be seen that Liebig's classification into flesh-formers and body-warmers is not a true one. Proteids, fats, and starches are sources of heat in the body, though it is principally derived from fats and starches; on the other hand, fats and starches play their part in building up the tissues of the body, and indirectly assist in the storage of proteid material. Further, the fat stored in the body, which is the great source of heat, may be produced from the fats themselves, the carbohydrates, or the proteids; and, under certain conditions, as in diabetes, carbohydrates may be produced from proteids.

The characteristic feature of proteid food is, that it increases the oxidative and metabolic activity of the tissues, tending to a rapid consumption, not only of itself, but of non-nitrogenous food as well (Foster).

CHAPTER X.

MILK, TEA, AND ALCOHOL AS ARTICLES OF DIET.

95. **The Composition of Milk.**—Milk is an ideal food; it contains, in excellent proportions, proteids, fats, and sugars in the most easily digestible form, and the inorganic salts present are those which are of the greatest importance to the body. Cow's milk is of the most variable composition within certain limits. The kind of cow, the pasture, the time of year, and many other circumstances, affect the relations of the various constituents.

The average composition as given by Parkes is as follows:—

	Per Cent.
Water, . .	86·8
Proteids, . .	4·0
Fats, . . .	3·7
Carbohydrates, .	4·8
Salts, . .	·7
	100·0

The chief points of difference between cow's milk and human milk is that the former contains higher percentages of fats and proteids and less sugar. The average specific gravity of cow's milk is about 1031, water being taken as 1000. This is affected, however, by the amount of

fat present, which is the most variable constituent. The fat or cream is measured by means of a creamometer, which is a measuring tube divided into a hundred parts. On letting a sample of milk stand for twenty-four hours in such a vessel, the percentage of cream by volume may be read off. This may vary in pure milk from 2 to 26 per cent., the average being 8 to 12 per cent. In some cases the amount of cream is taken as the standard of purity—*e.g.*, at the Liverpool Workhouse the standard is 10 per cent. For every degree above this ½d. per gallon is added, and a like amount deducted if it falls below.

The proteids present in milk are casein and albumen. The casein is in some way associated with the calcium phosphate present, which holds it in solution. By the action of bacteria (*bacterium lactis*) milk-sugar ($C_{12}H_{22}O_{11}$) is converted into lactic acid ($C_3H_6O_3$), as represented by the equations

$$C_{12}H_{22}O_{11} + H_2O = 2\ C_6H_{12}O_6$$
$$C_6H_{12}O_6 = 2\ C_3H_6O_3.$$

The free acid acts upon the neutral calcium phosphate, converting it into acid calcium phosphate, and the casein is precipitated. The production of lactic acid goes on more rapidly when warm; therefore milk should be kept in a cold place in hot weather, to prevent souring. When quite fresh, milk is slightly alkaline; after a few hours it becomes neutral, and then slightly acid. On boiling milk, the abumen is coagulated; but the casein remains in solution.

96. **Milk as a Food.**—The value of milk as a food cannot be over-estimated. The proportions of carbon to nitrogen approximate to those required to sustain the daily loss, so that there is very little waste, and the ease of assimi-

lation of the various constituents, makes it possible to take this variety of food when others would be impossible of digestion.

In infancy it is especially valuable, the large amount of salts required for the formation of bone being present in suitable proportions, in addition to the other tissue-forming constituents.

The point of difficulty often experienced in the digestion of milk is due to the clotting by the action of the gastric juice, which prevents the rapid conversion of the proteids into peptones. This may be partially remedied by such substances as pearl-barley water, which prevent the particles of casein coming close together to form a clot, and thus make it easier for the gastric juice to do its work; or the casein may be precipitated artificially by acid or rennet, and the clots broken up into fine particles before taking it.

Warm milk is often found to be more digestible than cold. This is not due to any chemical change in the direction of greater digestibility, as the only effect of heating is the coagulation of the albumen, which is very nutritious and digestible. The effect is produced by the warmth causing a more rapid flow of the digestive secretions.

Milk is not sufficiently valued as a food in England, especially the varieties known as skim and butter-milk, although they still contain the most valuable constituents. Analyses of the different kinds gave the following results:—

1 pint of pure milk contains 640 grains of carbon and 57 grains of nitrogen.

1 pint of skimmed milk contains 516 grains of carbon and 55 grains of nitrogen.

1 pint of butter-milk contains 490 grains of carbon and 55 grains of nitrogen.

Thus they are all rich nitrogenous foods, the only difference being that the removal of the fat in skim and buttermilk reduces the amount of carbonaceous material.

97. **Analysis of Milk.**—If left to itself, milk naturally separates into fat, proteids, and a solution of milk-sugar and salts. The fat particles being lighter, gradually rise to the surface and form the cream layer. This separation may be effected efficiently in a few minutes by means of a centrifugal machine. The casein is gradually deposited in curdy masses, as the lactic acid produced from the milk-sugar becomes sufficiently strong. This may also be brought about artificially by adding a free acid to fresh milk.

After the removal of the fat and proteids, the whey may be partly evaporated to drive off a large portion of the water, and crystals of milk-sugar will be deposited on cooling.

In analyses of milk the most important determinations are the total solids, the fat, the non-fatty solids, and the ash. The total solids are determined by placing a known weight of milk in an evaporating basin, driving off the water on a water-bath, and drying in a water-oven until no more vapour is given off. The weight, after deducting that of the evaporating basin, gives the amount of total solids.

To determine the amount of fat, a known weight of milk is evaporated as before, almost to dryness, and then treated with ether several times, the solid residue being stirred with a glass rod to bring every particle into contact with the ether. Ether dissolves the fat, but no other constituent of the milk. If, therefore, the various washings with ether are poured into a weighed vessel, and the ether driven

off, the fat is left in the vessel, and the increase in weight gives the amount in the quantity of milk taken.

After removal of the fat, the remaining solids in the former experiment are dried in a water-oven, and the weight of the non-fatty solids is obtained. In the determination of the total solids, fat, and non-fatty solids, the temperature is never raised above the boiling point of water, so that no organic matter is decomposed or driven off.

The amount of ash is very easily determined: a given weight of milk is evaporated in a weighed dish, and the temperature is then raised to a red-heat. The organic matter is thus destroyed, and the residue consists of the inorganic salts, the amount of which is shown by the increase in weight of the dish.

In a full analysis, the amount of sugar can be determined by its power of reducing Fehling's solution (p. 124), or by means of the polariscope. The quantity of proteid may also be found by determining the amount of nitrogen by an organic analysis. The weight of nitrogen multiplied by 6·3 gives the amount of proteid.

98. **Adulteration of Milk, and Methods of Detection.**—The natural variation in composition in different samples of pure milk renders it very difficult to detect slight adulteration. Water is the chief adulterant, the effect of which is to lower the specific gravity and reduce the quantity of total solids.

The specific gravity of milk is so affected by the presence of cream that a judicious removal of this substance and addition of water may keep the specific gravity the same as before adulteration. It is therefore advisable to remove the cream before the determination of the specific gravity. The specific gravity is determined by carefully weighing a known

volume of milk, and comparing it with the weight of the same volume of water under the same conditions; or, more readily, by using a lactometer, which floats in the liquid at different levels, depending on the specific gravity. If, after removal of the cream, the specific gravity is below 1028, the milk has probably been watered. The removal of cream, or the addition of water, or both, would lead to a diminution of the total solids: this determination is therefore of great importance in the detection of adulteration. In cases of skilful adulteration, however, solid material is added with the water, which not only raises the specific gravity, but also increases the amount of total solids. If an inorganic substance is added for this purpose, it may be detected by the large amount of ash, but where, as is often the case, cane-sugar is used, the difficulties of detecting the adulteration are much increased, and a full analysis must be resorted to.

A high specific gravity and low percentage of fat would be evidence in favour of cream having been taken from the milk.

Another class of adulterants of which the detection is less difficult, embraces such compounds as sodium carbonate, salicylic acid, borax, boracic acid, and boro-glyceride, which are added for the purpose of preservation, and so enable the dealer to sell old milk as new.

As we have seen, the souring of milk is due to the conversion of milk-sugar into lactic acid by bacterial action. If sodium carbonate is present, the acid as it is formed is neutralised by the alkaline sodium carbonate, sodium lactate being formed, and carbonic acid gas evolved. If this body is present in excess, the addition of an acid gives rise to effervescence, and the gas evolved gives the char-

acteristic tests for carbonic acid. The ash is also found to give the reactions for sodium carbonate. In this case bacterial action is not prevented, but curding may be delayed for several days, because this can only take place in an acid solution.

The other substances are added for the purpose of preventing the bacteria carrying on their work.

Salicylic acid may be detected by the addition of a solution of perchloride of iron, which gives a deep purple colour with this compound.

The compounds of borax and boracic acid are best detected by adding some alcohol and a small quantity of strong sulphuric acid to the suspected milk, and heating in an evaporating basin. The alcohol being given off before the milk boils, can be set on fire, and if any of these compounds are present, the borders of the flame will have a characteristic green colour.

As accurate methods of analysis and reliable tests for adulterants are discovered, adulteration becomes less and less practised. Thus, in the present day, milk, in common with other foods, is much purer than formerly, due rather to advances in chemistry, by which detection of adulteration is made easy, than to any improvement in commercial morality.

99. **Milk and the Spread of Disease.**—Milk is a very suitable medium for the existence and propagation of low forms of plant life; thus, bacteria and spores floating in the air, on coming into contact with milk, may be transferred in an active condition to individuals drinking it. In addition to this, milk has a peculiar power of absorbing poisonous gases and vapours.

In a paper read before the International Medical Con-

gress in 1881 by Mr Ernest Hart, it was stated that fifty epidemics of typhoid fever, fifteen of scarlet fever, and six of diphtheria had been traced to milk as the source of infection; since this, numerous cases have been recorded.

It is stated also that milk, which has stood some time in air, in which fermentative changes are going on, may give rise to serious disorders, especially in children.

The introduction of specific germs of disease into milk may take place in a variety of ways, such as washing the tins, or adulterating with polluted water, or by the milk being exposed to polluted air.

In large dairies the habit of mixing quantities of milk from different sources aids in the dissemination of disease germs where one sample is polluted.

If milk is exposed to the temperature of boiling water for five minutes, all living germs are destroyed; and, after thus sterilising, if the containing vessel is sealed up to prevent the entrance of bacteria, milk can be kept for an indefinite period without souring.

100. **Composition of Tea.**—Green and black teas are produced from the same plant, *Thea Sinensis*. The difference in appearance and properties are entirely due to the method of preparation. In the case of green tea, the processes of drying and rolling the leaves are carried on as quickly as possible, so as to prevent as far as possible any fermentative changes. In the manufacture of black tea, however, the processes are carried on slowly, and ample opportunities are given for fermentation. The result is that there is a considerable difference in chemical composition between the two kinds, as shown in the following analyses given by Bell. The black tea was Congou at 2s. 10d., and the green tea, Young Hyson, at 3s. per lb.—

	Congou.	Young Hyson.
Moisture . . .	8·20	5·96
Theine . . .	3·24	2·33
Albumen, insoluble .	17·20	16·83
Albumen, soluble .	·70	·80
Extractives . .	6·79	7·05
Dextrin, or gum .	—	·50
Pectin and Pectic Acid	2·60	3·22
Tannin . . .	16·40	27·14
Chlorophyll . .	4·60	4·20
Cellulose . . .	34·00	25·90
Ash	6·27	6·07
	100·00	100·00

The most important points of difference are the relative quantities of theine and tannin; the sample of black tea containing 1 per cent. more theine and 10 per cent. less tannin than the green.

The volatile oil, to which the peculiar odour of tea is due, is present in very small quantities. It can be separated by heating dry tea in a retort to a fairly high temperature, when the oil drops collect on the cooler portions of the glass.

Theine is the most important constituent of tea, and it is to this body chiefly that its remarkable physiological properties are due. If some powdered tea is placed in a basin on a hot plate kept at a temperature of about 200° C., and a cold surface is held over it, feathery crystals of theine will be deposited. Theine is a definite chemical compound, having the composition $C_8H_{10}N_4O_2$. The proteids present being insoluble, do not pass into the infusion of tea, and are therefore wasted, unless the leaves are eaten, as in Tartary. The presence of sodium carbonate is said

to make these more soluble, but it also has the effect of bringing more tannin into solution.

The astringent properties of tea are due to the presence of tannin, which is present in large quantities, and is fairly soluble. This substance has the effect of precipitating peptones in the stomach, and therefore seriously retards digestion. In some of the best China teas the time of infusion does not affect the amount of tannin dissolved, but with ordinary teas it affects it considerably, especially in the Indian varieties. Thus, in the experiments of Dr Hale White, it was found that the relation of the amount of tannin dissolved with an infusion of three minutes' standing, to that with an infusion of fifteen minutes, was as 11 to 17. Sodium carbonate also increases the amount dissolved. The depth of the black coloration given with tannin, on addition of iron salts, gives a ready method of roughly comparing the quantities in different infusions.

101. **Physiological action of Tea.**—Tea can have no claims as a direct food, since the soluble constituents which may be used in the body either for repairing tissue or the supply of energy are in such small proportions. The substances taken with tea, however, such as milk and sugar are valuable foods.

There is a great diversity of opinion as to the physiological action of tea. It is said that it prevents nitrogenous metabolism, and should therefore be used where the supply of food is limited, and where powers of endurance are called into play. It is recommended to take it between meals, because of its retarding influence on digestion, and the habit of taking it with meat, as in "high teas," is generally condemned.

Dr Edward Smith, on the other hand, as a result of

numerous experiments, concludes that it increases respiratory action, and takes an important part in aiding metabolism, and advises its use in helping to get rid of an excess of food after a heavy meal. He says, "The conclusion at which we arrived, after our researches in 1858, were, that tea should not be taken without food, or by the young or very feeble; and that its essential action is to waste the system or consume food, by promoting vital actions which it does not support." All authorities agree in condemning the excessive use of tea.

As to the immediate effects, there is no doubt. It refreshes the body, principally by promoting perspiration, and thus producing a cooling effect by evaporation. It quickens the intellect, takes away the desire for sleep, and generally increases the capacity for work.

102. **The Adulteration of Tea.**—The most important substances used in the adulteration of tea may be divided into three groups.

(1.) Inorganic substances, such as sand, quartz, &c., which are added to common teas to increase the weight. They can be detected by microscopic examination, and also by the increase in the amount of ash.

(2.) Colouring matters, such as turmeric, prussian blue, and indigo, which are used for the purpose of giving a green colour to inferior black teas. These compounds may be recognised by individual tests.

(3.) Exhausted tea leaves and leaves of other plants, such as the willow, elder, sloe, &c. Microscopic examination of the leaves is generally sufficient to detect adulteration of this kind. When exhausted leaves are used, a very weak solution is produced, and the soluble salts are absent, having been removed in the previous infusion.

103. **Composition of Alcoholic Beverages.** — Alcohols constitute an important series of organic substances. Ethyl alcohol (C_2H_6O) is the one found normally in alcoholic beverages. It contains 52·2 per cent. of carbon, 13 per cent. of hydrogen, and 34·8 per cent. of oxygen. Other alcohols, such as fusel-oil (amylic alcohol) are often present, especially in cheap spirits, and are very injurious.

The percentage of alcohol contained in some of the more important spirits, wines, and beers, is given in the following table :—

Brandy,	50 to 60	per cent.	alcohol.
Gin,	49 „ 60	„	„
Whisky,	50 „ 60	„	„
Rum,	60 „ 77	„	„
Port,	16 „ 23	„	„
Sherry,	16 „ 25	„	„
Madeira,	16 „ 22	„	„
Champagnes,	6 „ 13	„	„
Rhine wines,	7 „ 16	„	„
English beers,	5 „ 7	„	„
German „	3 „ 7	„	„

In addition to the alcohol, there are substances present in most alcoholic beverages which are recognised food-stuffs. Thus in beer—

1 pint (20 oz.) contains on average—

Alcohol,	1 ounce.
Extractives (dextrin, sugar),	1·2 „
Free acid,	25 grains.
Salts,	13 „

104. **Physiological action of Alcohol.**—The question of the action of alcohol on the body is a very difficult one,

and one upon which authorities differ to a considerable extent. In excess, alcohol has a disastrous effect morally and physiologically, and the natural prejudice against it on this account often introduces an element of bias into the consideration of its action in small quantities.

It is generally agreed that the limit of the quantity of alcohol which can be taken into the system with safety is 1 to 1½ ounces in 24 hours; this amount is represented by about 1 to 1½ pints of beer, ½ to ¾ of a pint of claret, or ⅓ of a pint of sherry or port per day.

At first sight, it appears that alcohol should be a valuable agent as a heat-producer. When it is burnt in air, it is converted into carbonic acid and water, with considerable evolution of heat, thus :—

$$C_2H_6O + 3O_2 = 2CO_2 + 3H_2O.$$

It is certain, however, that this does not represent the change which takes place in the body, as the general effect of alcohol is to diminish rather than increase the amount of carbonic acid given off. Some of the alcohol undoubtedly passes out of the body unchanged, and the balance of evidence is in favour of the rest being converted into acetic acid ($C_2H_4O_2$)

$$C_2H_6O + O_2 = C_2H_4O_2 + H_2O,$$

the acetic acid being converted in the blood into sodium acetate.

If we assume this to be the correct explanation of the changes which take place on the introduction of alcohol, we see the reason for the diminished natural oxidation which goes on in the body, oxygen having been removed from the blood to convert the alcohol into acetic acid. The tendency of beer drinkers to become corpulent cannot be due alone to the small quantity of dextrin and

sugar which beer contains, it must arise also from the diminished oxidation, leading to a storage of fat. This would also partially explain the action of alcohol in lowering the temperature of the body.

105. **The action of Alcohol as a Food.**—When the small amount of alcohol which can be taken per day without injury is taken into consideration, and also the fact that a portion of this undergoes no change, and further, the comparatively small evolution of heat when alcohol is converted into acetic acid, the value of alcohol as a direct food approaches the vanishing point.

Any claim it may have as a food is an indirect one, due to its shielding action in regard to oxidation, and its action with regard to digestion. In this question, the action of alcohol must be separated from the substances taken with it in beverages, such, for example, as the dextrin and sugar in beer. Thus, rum and milk is an excellent food, though not of a higher value than milk alone; but in some cases the milk alone could not be properly digested.

The bitter principles in beer stimulate the secretions and sharpen the appetite, and thus in small quantities aid digestion. Excess of alcohol, however, has a paralysing action, especially on gastric digestion. It has been found that sherry taken with meat increases the time taken for digestion three-fold. Acid wines, by their action in neutralising the alkalinity of the saliva, seriously interfere with the conversion of starch into sugar; and where these are taken, it is well to have alkaline waters to counteract this effect.

Sir W. Roberts concluded, from his investigations on the action of wines on digestion, that port and sherry exercise a serious retarding effect; that large quantities of light wines have a powerful influence on peptic digestion, sparkling wines being less harmful than still ones; and that

small quantities do not produce any appreciable retarding effect, but act as pure stimulants.

Brandy, whisky, and gin have a marked effect on salivary digestion, preventing the conversion of starch into sugar, gin being the least harmful.

The general conclusions are (1) that a man in health does not require alcohol, but that it should be looked upon rather as a medicine; and (2) that, in small quantities in a suitable form, it quickens the appetite and aids digestion; and (3) that it should be regarded as a stimulant or relish rather than as a food.

106. **Adulteration of Alcoholic Beverages.**—Spirits prepared from grain and potatoes by distillation often contain the higher alcohols, such as fusel-oil, which are most harmful. Their presence can be detected by the boiling point, which is higher than that of ethyl alcohol, these impurities being left in the retort on distillation at 100° C. The principal adulteration in beers is water, and in some cases inorganic salts are added, which produce a feeling of thirst.

In the manufacture of wines there is a fertile field for adulteration, both as regards colouring matters, flavouring principles, and other substances. On the occasion of the failure of the grape in a certain area in France some years ago, it is stated that the exportation of wine from the district was not seriously affected.

The plastering of wines is very common; this consists in the addition of sulphate of lime. The reason for the adulteration is, that during the fermentation of wine, cream of tartar is deposited, due to its diminished solubility in water containing large quantities of alcohol. The turbidity thus produced is removed by the presence of sulphate of lime, tartrate of lime is precipitated, potassium sulphate passes into solution, and the wine becomes clear.

INDEX.

A

ABSORPTION of gases by blood, 64.
charcoal, 38.
milk, 152.
water, 62.
Acetic acid, 158.
Acid, definition of, 14.
Ague, 103.
Air, a mixture of gases, 35.
bacteria in, 115.
colds increased by impure, 82.
definition of vitiated, 72.
determination of impurities in, 74.
organic matter in, 75.
difference between inspired and expired, 56.
diffusion of, 70.
impurities in, 67.
purification of, 69.
by plants, 71.
by rain, 71.
by wind, 70.
stationary and tidal, 61.
vitiated, 71, 81, 82.
water vapour in, 33, 71.
Air-cells of lungs, 60.
Albumen, 131, 142.
Alcohol as a food, 159.
heat-producer, 158.
composition of ethyl, 157.
physiological action of, 157, 159.
Alcoholic beverages, adulteration of, 160.
composition of, 157.
Alum, test for, in bread, 139.
Ammonia, absorption by charcoal 38.
properties of, 31.
Animal charcoal, 40.
action on coloured liquids of, 40.
food, 141.
Antiseptics, 114.
Aqueous vapour in air, 33, 71.
determination of amount, 34.
Argo case of impure water, 103.
Arteries, 58.
Atmosphere, chemical composition of, 20.
composition by volume of, 22, 24.
weight of, 21.
extent of, 19.
pressure of, 17.
sources of impurities in, 67.
Atoms, definition of, 6.
Avogadro's law, 8

B

BACTERIA, action of, 113.
importance of, 116.
in air and water, 82, 116.
in milk, 114, 147, 152.
nature of, 111.
Bacterium lactis, 114, 147.
Baking powders, 137.
Barometer, construction of, 18.
experiments illustrating action of, 19.
principle of, 17.
Bases, definition of, 14.
Beer, action on digestion of, 159.

Beer, adulteration of, 160.
composition of, 157.
Bile, action of, 125.
Blood, 57.
arterial and venous, 64.
changes in, 63.
passage of food into, 127.
vessels, 58.
Body, daily loss of, 128.
heat of, 65, 145.
Body-warmers, 143.
Boiling point, 90.
influence of pressure on, 90.
Borax in milk, 151.
test for, 152.
Boyle's law, 51.
Bread, adulteration of, 138.
aerated, 137.
as an article of diet, 133.
brown, 135.
change on keeping, 135.
chemical changes in baking, 133, 136.
compared with meat, 139.
composition of, 133.
crust and crumb of, 134.
Dauglish method of raising, 137.
detection of adulteration in, 138.
digestibility of, 131, 135.
methods of raising, 136.
object of adulteration of, 138.
wheat-meal, 136.
white, 135.
Breathing space required, 72.
Bronchi, 60.
Bronchial tubes, 60.

C

CAPILLARIES, 59, 61, 127.
Carbohydrates, 122, 124, 131, 134, 142, 143, 147.
action of, 143.
Carbon, allotropic modifications of, 37.
Carbon, amount given off daily, 129.
Carbon monoxide, action on blood, 47.
in water-gas, 46.
preparation of, 46.
properties of, 47, 64.
Carbonic acid, absorption by blood of, 63.
charcoal of, 38.
action of green plants on, 41, 45, 71.
amount in atmosphere, 32, 72.
inspired and expired air, 57.
London theatres, 74, 79.
composition of, 41.
constituent of plant food, 32.
determination of amount in air, 32, 74.
heat of formation of, 31.
preparation of, 43.
properties of, 44.
raising of bread by, 44, 136.
vitiation of air by, 32, 68, 73.
Carboxyhæmoglobin, 47, 64.
Casein in milk, 147, 149.
Charcoal, 37.
absorption of gases by, 38.
action on gases, 38.
liquids, 40.
organic matter, 41.
filters, 109.
Chlorophyll, action of, 45.
Chemical changes, 1.
Chemistry, definition of, 2.
Cholera, 105.
in Glasgow, 105.
Coal gas, composition of, 47.
illuminating power of, 48.
Combustion, carbonic acid produced in, 68.
theory of, 29.
Compounds, definition of, 4.
Cooking, effect on digestibility of, 131.
methods of, 140.
temperature of, 131.

Copper salts in bread, 138.
Corpuscles of blood, 57, 64.
Cream in milk, 147, 149.

D

Dew-point, 33.
Diamond, 37.
Diet, bread and meat as articles of, 133.
milk, tea, and alcohol, 146.
necessity for a mixed, 129.
Diffusion in lungs, 61.
in ventilation, 70.
of gases, 52.
thermal, 71.
Digestibility, effects of cooking on, 131.
of eggs, 132.
Digestion, effect of alcohol on, 159.
object of, 118.
Digestive apparatus, 119.
Diphtheria, 153.
Distillation, 108.
Draught, definition of, 75.

E

Eggs, digestibility of, 132.
Elements, definition of, 4.
list of, 11.
Emulsification of fats, 125.
Enteric fever, 104, 153.
Epidemics and impure water, 102.
Equations, chemical, 12.
Eudiometer, 22, 88.
Extracts of meat, 122, 140.

F

Faraday's Experiment, 57.
Fats, 122, 130, 134, 139, 143, 147.
action of, 145.
determination of, in milk, 149.
emulsification of, 125.
Fehling's solution, 124, 150.
Fermentation, 44, 68, 136.
Fever, enteric, 104, 153.
malarial, 103.
scarlet, 153.
Filters, charcoal, 109.
requirements of, 109.
spongy iron, 111.
Filtration, 108, 109.
Flesh-formers, 143.
Food, 118, 119, 121, 141.
alcohol as a, 159.
comparison of animal and vegetable, 141.
definition of, 118.
passage of, into blood, 127.
required, to repair loss, 128.
Food-stuffs, classification of, 121.
Formulæ, 12.
Freezing, expansion of water on, 93.
point, 16.
Frankland's experiments on combustion of foods, 143.
impure water, 110.
Fusel-oil, 157, 160.

G

Gases, absorption by charcoal of, 38.
constitution of, 48.
density of, 52.
diffusion of, 52, 61.
expansion of, 50.
interchange of, in lungs, 61.
pressure of, 49.
solubility in water of, 62.
variation with pressure of, 51.
velocity of, 50.
volume in blood, 65.
Gastric juice, 123.
action of, 124.
Germs, spread of diseases by, 114.
Glasgow, cholera in, 105.
water-supply, 103.
Graphite, 37.

H

HÆMOGLOBIN, 58, 64.
Hardness in water, 95.
permanent, 96.
temporary, 96.
Health, effect of impure air on, 71, 81.
effect of hard water on, 97.
effect of impure water on, 102.
influence of ventilation on, 67.
Heat, latent and specific, 91.
Hinckes-Bird ventilator, 77.
Hooke and Mayow, 20, 29.
Hope's experiment, 94.
Hydrogen, molecular weight of, 9.
preparation of, 84.
properties of, 85.
velocity of molecules of, 50.
Hygrometers, 34.

I

ILLUMINANTS, 47.
Inlets and outlets in ventilation, 76, 78.
Inspiration and expiration, 61.
Intestine, structure of small, 127.

K

KOCH on bacteria, 114.

L

LACTIC acid, 147.
Lactometer, 151.
Latent heat of water, 91.
Lavoisier, 2, 30.
Lead in water, 101.
Liebig's classification of foods, 143.
extract, 122, 140.
Lister, work on antiseptics, 115.
Logwood test for alum, 139.
London water-supply, 100, 105.
Lungs, amount of air in, 61.
circulation of, 61.
gaseous interchange in, 63.
structure of, 60.
Lymphatic plexus, 127.

M

MACKINNEL'S ventilator, 79.
Malarial fever, 103.
Matter, indestructibility of, 2.
Meat, as an article of diet, 139.
compared with bread, 139.
composition of, 139,
digestibility of, 131, 140.
methods of cooking, 140.
Metabolism, 65, 129, 144, 156.
Metric system, 15.
Milk, adulteration of, 150.
analysis of, 148, 149.
as a food, 147.
composition of, 146.
connection with spread of disease, 152.
difference between human and cow's, 146.
digestion of, 147.
infected, 104.
percentage of cream in, 147.
souring of, 114, 147, 151, 153.
sterilisation of, 153.
Millbank case of impure water, 102.
Miners, mortality of Cornish, 83.
Mines, ventilation in, 82, 83.
Mixtures, chemical, 5.
Molecular weights, 8.
Molecules, definition of, 7.
size of, 8.
velocity of, 8.
Mycoderma aceti, 113.

N

NITROGEN, a constituent of tissues, 143.

Nitrogen, amount given off from body, 129.
function of, in atmosphere, 26.
preparation of, 31.
properties of, 31.
velocity of molecules of, 50.
Nunney case of impure water, 104.

O

ORGANIC matter in air, 72.
determination of, 75.
in water, 97, 98.
Oxygen, absorption by blood, 63.
charcoal, 38.
action in combustion, 27.
disease, 26.
polluted rivers, 25.
in soil, 26.
on animal life, 27, 69.
on non-metals, 28.
fish dependent on, 26.
importance in respiration, 25.
plants dependent on, 26.
preparation of, 27.
properties of, 28.
storage in tissues of, 65.
velocity of molecules of, 50.
Oxyhæmoglobin, 64.
Oxyhydrogen flame, 48.
Ozone in air, 32.
detection of, 35.

P

PANCREATIC juice, action of, 126.
Parasites, 141.
Peptones, 126, 142.
Permanent hardness in water, 96.
Pettenkofer, 70, 72.
Phlogistic theory, 30.
Phthisis, 81.
Physical changes, 1.
Plants, action of, on carbonic acid, 45.
function of, in rivers and lakes, 107.
storage of energy in, 44.
Potassium permanganate test for water, 106.
Pressure, atmospheric, 17.
influence on boiling point, 90.
law of, 50.
production of, 49.
standard,
Priestley, 20, 22, 27.
Prisons, air of, 81.
illness in, 105.
water at Millbank, 102.
Proteids, 121, 125, 130, 134, 139, 141, 143, 147, 150.
action of, 43.
coagulation of, 131, 132.
digestibility of, 132.
Pulmonary artery, 59, 61.
veins, 59, 61.

R

RAIN, purifying action of, 71.
Respiration, 54, 68, 72.
in fishes, 54.
mechanics of, 55.
object of, 54.

S

SALICYLIC acid in milk, 151.
test for, 152.
Saliva, 119.
action of, 122.
Salts, definition of, 14.
Scarlet fever, 153.
Scurvy, 122.
Serum of blood, 58, 63, 65.
Sherringham valve, 78.
Silicated carbon in filters, 110.
Soap, action of hard water on, 95.

Soap, composition of, 95.
curding of, 96.
Sodium carbonate in milk, 151.
tea, 155.
test for, 151.
Specific heat of water, 91, 92.
gravity of milk, 146, 150.
Spirits, action on digestion, 160.
composition of, 157.
Starch, 123, 124.
Stomach, 120.
Suffocation, 66.
Sugar, fermentation of, 44, 136.
in milk, 147, 150.
Sulphuretted hydrogen, absorption by charcoal of, 38.
action of oxygen on, 39.
test for, 40.
Sylvester's scheme of ventilation, 80.
Symbols, chemical, 10.
Sweat-glands, 66.

T

TANNIN, 155.
test for, 155.
Tea, adulteration of, 156.
astringent properties of, 155.
comparison of black and green, 154.
composition of, 153.
manufacture of black and green, 153.
physiological action of, 155.
Temperature, absolute zero of, 51.
effect of differences of, in ventilation, 70.
of coagulation, 131.
standard, 16.
Temporary hardness in water, 95.
Thea sinensis, 153.
Theine, 154.
Tobin's tubes, 78.
Trachea, 60.
Trypsin, 126.
Typhoid fever, 104, 153.

V

VALVES of blood-vessels, 58.
Vegetable foods, 141.
Veins, 59.
Ventilator, Hinckes-Bird, 77.
Mackinnel's, 79.
Sherringham's valve, 77.
Tobin's tube, 78.
Ventilation, 67, 73, 75, 80.
action of wind in, 68.
effect on health of, 67.
in cattle sheds, 82.
in Hospital Lariboisière, 80.
in mines, 82, 83.
in prisons, 81.
methods of, 76, 80.
object of, 75.
Sylvester's scheme of, 80.
Vitiated air, 71, 81, 82.

W

WATER, a compound, 85.
action on metals, 101.
rocks, 93.
analysis of London, 100, 105.
Argo case of impure, 103.
bacteria in, 116.
boiling point of, 16, 90.
changes in volume of, 93.
composition by volume, 87.
weight, 86.
connection with spread of disease, 103.
determination of hardness in, 96.
different kinds of, 106.
effect on fish of impure, 108.
health of hard, 97.
freezing point of, 16.
hardness of, 95.
heat of formation of, 31.
impure, 97, 98, 100, 102.
latent heat of, 91.
maximum density of, 93.

Water, Millbank Prison case of impure, 102.
necessity for pure, 85.
organic impurities in, 97.
purification by artificial means, 108.
natural means, 107.
recognition of impurity in, 106.
solubility of gases and solids in, 95.
specific heat of, 91.
three states of, 90.
Yerrauda case of impure, 105.
Weights and measures, 15.
Wells, deep and shallow, 104, 106.
Wind, action of, in ventilation, 69.
Wines, action on digestion of, 159.
adulteration of, 160.
composition of, 157.
plastering of, 160.
souring of, 113.

Y

YEAST, 44, 136.
Yerrauda case of impure water, 105.

TURNBULL AND SPEARS, PRINTERS, EDINBURGH.

A LIST OF NEW BOOKS
AND ANNOUNCEMENTS OF METHUEN AND COMPANY

PUBLISHERS : LONDON
18 BURY STREET
W.C.

CONTENTS

	PAGE
FORTHCOMING BOOKS,	2
POETRY,	6
HISTORY AND BIOGRAPHY,	7
GENERAL LITERATURE,	8
WORKS BY S. BARING GOULD,	9
FICTION,	10
NOVEL SERIES,	11
BOOKS FOR BOYS AND GIRLS,	12
ENGLISH LEADERS OF RELIGION,	13
UNIVERSITY EXTENSION SERIES,	14
SOCIAL QUESTIONS OF TO-DAY,	15

OCTOBER 1892

MESSRS. METHUEN'S
AUTUMN ANNOUNCEMENTS

GENERAL LITERATURE

Rudyard Kipling. BARRACK-ROOM BALLADS; And Other Verses. By RUDYARD KIPLING. *Extra Post 8vo, pp. 208. Laid paper, rough edges, buckram, gilt top.* 6s.

A special Presentation Edition, *bound in white buckram, with extra gilt ornament.* 7s. 6d.

The First Edition was sold on publication, and two further large Editions have been exhausted. The Fourth Edition is Now Ready.

Gladstone. THE SPEECHES AND PUBLIC ADDRESSES OF THE RT. HON. W. E. GLADSTONE, M.P. With Notes. Edited by A. W. HUTTON, M.A. (Librarian of the Gladstone Library), and H. J. COHEN, M.A. With Portraits. *8vo. Vol. IX.* 12s. 6d.

Messrs. METHUEN beg to announce that they are about to issue, in ten volumes 8vo, an authorised collection of Mr. Gladstone's Speeches, the work being undertaken with his sanction and under his superintendence. Notes and Introductions will be added.

In view of the interest in the Home Rule Question, it is proposed to issue Vols. IX. and X., which will include the speeches of the last seven or eight years, immediately, and then to proceed with the earlier volumes. Volume X. is already published.

Collingwood. JOHN RUSKIN: His Life and Work. By W. G. COLLINGWOOD, M.A., late Scholar of University College, Oxford, Author of the 'Art Teaching of John Ruskin,' Editor of Mr. Ruskin's Poems. *2 vols. 8vo.* 32s.

Also a limited edition on hand-made paper, with the Illustrations on India paper. £3, 3s. *net.*

Also a small edition on Japanese paper. £5, 5s. *net.*

This important work is written by Mr. Collingwood, who has been for some years Mr. Ruskin's private secretary, and who has had unique advantages in obtaining materials for this book from Mr. Ruskin himself and from his friends. It will contain a large amount of new matter, and of letters which have never been published, and will be, in fact, as near as is possible at present, a full and authoritative biography of Mr. Ruskin. The book will contain numerous portraits of Mr. Ruskin, including a coloured one from a water-colour portait by himself, and also 13 sketches, never before published, by Mr. Ruskin and Mr. Arthur Severn. A bibliography will be added.

Baring Gould. THE TRAGEDY OF THE CAESARS: The Emperors of the Julian and Claudian Lines. With numerous Illustrations from Busts, Gems, Cameos, etc. By S. BARING GOULD, Author of 'Mehalah,' etc. *2 vols. Royal 8vo.* 30*s.*

This book is the only one in English which deals with the personal history of the Caesars, and Mr. Baring Gould has found a subject which, for picturesque detail and sombre interest, is not rivalled by any work of fiction. The volumes are copiously illustrated.

Baring Gould. SURVIVALS AND SUPERSTITIONS. With Illustrations. By S. BARING GOULD. *Crown 8vo.* 7*s.* 6*d.*

A book on such subjects as Foundations, Gables, Holes, Gallows, Raising the Hat, Old Ballads, etc. etc. It traces in a most interesting manner their origin and history.

Perrens. THE HISTORY OF FLORENCE FROM THE TIME OF THE MEDICIS TO THE FALL OF THE REPUBLIC. By F. T. PERRENS. Translated by HANNAH LYNCH. In three volumes. Vol. I. *8vo.* 12*s.* 6*d.*

This is a translation from the French of the best history of Florence in existence. This volume covers a period of profound interest—political and literary—and is written with great vivacity.

Henley & Whibley. A BOOK OF ENGLISH PROSE. Collected by W. E. HENLEY and CHARLES WHIBLEY. *Crown 8vo.* 6*s.*

Also small limited editions on Dutch and Japanese paper. 21*s.* and 42*s.*

A companion book to Mr. Henley's well-known *Lyra Heroica.*

"Q." GREEN BAYS: A Book of Verses. By "Q.," Author of 'Dead Man's Rock' &c. *Fcap. 8vo.* 3*s.* 6*d.*

Also a limited edition on large Dutch paper.

A small volume of Oxford Verses by the well-known author of 'I Saw Three Ships,' etc.

Wells. OXFORD AND OXFORD LIFE. By Members of the University. Edited by J. WELLS, M.A., Fellow and Tutor of Wadham College. *Crown 8vo.* 3*s.* 6*d.*

This work will be of great interest and value to all who are in any way connected with the University. It will contain an account of life at Oxford—intellectual, social, and religious—a careful estimate of necessary expenses, a review of recent changes, a statement of the present position of the University, and chapters on Women's Education, aids to study, and University Extension.

Driver. SERMONS ON SUBJECTS CONNECTED WITH THE OLD TESTAMENT. By S. R. DRIVER, D.D., Canon of Christ Church, Regius Professor of Hebrew in the University of Oxford. *Crown 8vo.* 6*s.*

An important volume of sermons on Old Testament Criticism preached before the University by the author of 'An Introduction to the Literature of the Old Testament.'

Prior. CAMBRIDGE SERMONS. Edited by C. H. PRIOR, M.A., Fellow and Tutor of Pembroke College. *Crown 8vo.* 6*s.*

A volume of sermons preached before the University of Cambridge by various preachers, including the Archbishop of Canterbury and Bishop Westcott.

Kaufmann. CHARLES KINGSLEY. By M. KAUFMANN, M.A. *Crown 8vo.* 5*s.*

A biography of Kingsley, especially dealing with his achievements in social reform.

Lock. THE LIFE OF JOHN KEBLE. By WALTER LOCK, M.A., Fellow of Magdalen College, Oxford. With Portrait. *Crown 8vo.* 5*s.*

Hutton. CARDINAL MANNING: A Biography. By A. W. HUTTON, M.A. With Portrait. *New and Cheaper Edition. Crown 8vo.* 2*s.* 6*d.*

Sells. THE MECHANICS OF DAILY LIFE. By V. P. SELLS, M.A. Illustrated. *Crown 8vo.* 2*s.* 6*d.*

Kimmins. THE CHEMISTRY OF LIFE AND HEALTH. By C. W. KIMMINS, Downing College, Cambridge. Illustrated. *Crown 8vo.* 2*s.* 6*d.*

Potter. AGRICULTURAL BOTANY. By M. C. POTTER, Lecturer at Newcastle College of Science. Illustrated. *Crown 8vo.* 2*s.* 6*d.*

The above are new volumes of the "University Extension Series."

Cox. LAND NATIONALISATION. By HAROLD COX, M.A. *Crown 8vo.* 2*s.* 6*d.*

Hadfield & Gibbins. A SHORTER WORKING DAY. By R. A. HADFIELD and H. de B. GIBBINS, M.A. *Crown 8vo.* 2*s.* 6*d.*

The above are new volumes of "Social Questions of To-day" Series.

FICTION.

Norris. HIS GRACE. By W. E. NORRIS, Author of 'Mdle. de Mersac,' 'Marcia,' etc. *Crown 8vo. 2 vols.* 21*s.*

Pryce. TIME AND THE WOMAN. By RICHARD PRYCE, Author of 'Miss Maxwell's Affections,' 'The Quiet Mrs. Fleming,' etc. *Crown 8vo. 2 vols.* 21*s.*

Parker. PIERRE AND HIS PEOPLE. By GILBERT PARKER. *Crown 8vo. Buckram.* 6*s.*

Marriott Watson. DIOGENES OF LONDON and other Sketches. By H. B. MARRIOTT WATSON, Author of 'The Web of the Spider.' *Crown 8vo. Buckram. 6s.*

Baring Gould. IN THE ROAR OF THE SEA. By S. BARING GOULD, Author of 'Mehalah,' 'Urith,' etc. Cheaper edition. *Crown 8vo. 6s.*

Clark Russell. MY DANISH SWEETHEART. By W. CLARK RUSSELL, Author of 'The Wreck of the Grosvenor,' 'A Marriage at Sea,' etc. With 6 Illustrations by W. H. OVEREND. *Crown 8vo. 6s.*

Mabel Robinson. HOVENDEN, V. C. By F. MABEL ROBINSON, Author of 'Disenchantment,' etc. Cheaper Edition. *Crown 8vo. 3s. 6d.*

Meade. OUT OF THE FASHION. By L. T. MEADE, Author of 'A Girl of the People,' etc. With 6 Illustrations by W. PAGET. *Crown 8vo. 6s.*

Cuthell. ONLY A GUARDROOM DOG. By Mrs. CUTHELL. With 16 Illustrations by W. PARKINSON. *Square Crown 8vo. 6s.*

Collingwood. THE DOCTOR OF THE JULIET. By HARRY COLLINGWOOD, Author of 'The Pirate Island,' etc. Illustrated by GORDON BROWNE. *Crown 8vo. 6s.*

Bliss. A MODERN ROMANCE. By LAURENCE BLISS. *Crown 8vo. Buckram. 3s. 6d. Paper. 2s. 6d.*

CHEAPER EDITIONS.

Baring Gould. OLD COUNTRY LIFE. By S. BARING GOULD, Author of 'Mehalah,' etc. With 67 Illustrations. *Crown 8vo. 6s.*

Clark. THE COLLEGES OF OXFORD. Edited by A. CLARK, M.A., Fellow and Tutor of Lincoln College. *8vo. 12s. 6d.*

Russell. THE LIFE OF ADMIRAL LORD COLLINGWOOD. By W. CLARK RUSSELL, Author of 'The Wreck of the Grosvenor.' With Illustrations by F. BRANGWYN. *8vo. 10s. 6d.*

Author of 'Mdle. Mori.' THE SECRET OF MADAME DE Monluc. By the Author of 'The Atelier du Lys,' 'Mdle. Mori.' *Crown 8vo. 3s. 6d.*

'An exquisite literary cameo.'—*World.*

New and Recent Books.

Poetry

Rudyard Kipling. BARRACK-ROOM BALLADS; And Other Verses. By RUDYARD KIPLING. *Fourth Edition. Crown 8vo.* 6*s.*

'Mr. Kipling's verse is strong, vivid, full of character. . . . Unmistakable genius rings in every line.'—*Times.*

'The disreputable lingo of Cockayne is henceforth justified before the world; for a man of genius has taken it in hand, and has shown, beyond all cavilling, that in its way it also is a medium for literature. You are grateful, and you say to yourself, half in envy and half in admiration: "Here is a *book*; here, or one is a Dutchman, is one of the books of the year."'—*National Observer.*

'"Barrack-Room Ballads" contains some of the best work that Mr. Kipling has ever done, which is saying a good deal. "Fuzzy-Wuzzy," "Gunga Din," and "Tommy," are, in our opinion, altogether superior to anything of the kind that English literature has hitherto produced.'—*Athenæum.*

'These ballads are as wonderful in their descriptive power as they are vigorous in their dramatic force. There are few ballads in the English language more stirring than "The Ballad of East and West," worthy to stand by the Border ballads of Scott.'—*Spectator.*

'The ballads teem with imagination, they palpitate with emotion. We read them with laughter and tears; the metres throb in our pulses, the cunningly ordered words tingle with life; and if this be not poetry, what is?'—*Pall Mall Gazette.*

Ibsen. BRAND. A Drama by HENRIK IBSEN. Translated by WILLIAM WILSON. *Crown 8vo.* 5*s.*

'The greatest world-poem of the nineteenth century next to "Faust." "Brand" will have an astonishing interest for Englishmen. It is in the same set with "Agamemnon," with "Lear," with the literature that we now instinctively regard as high and holy.'—*Daily Chronicle.*

Henley. LYRA HEROICA: An Anthology selected from the best English Verse of the 16th, 17th, 18th, and 19th Centuries. By WILLIAM ERNEST HENLEY, Author of 'A Book of Verse,' 'Views and Reviews,' etc. *Crown 8vo. Stamped gilt buckram, gilt top, edges uncut.* 6*s.*

'Mr. Henley has brought to the task of selection an instinct alike for poetry and for chivalry which seems to us quite wonderfully, and even unerringly, right.'—*Guardian.*

Tomson. A SUMMER NIGHT, AND OTHER POEMS. By GRAHAM R. TOMSON. With Frontispiece by A. TOMSON. *Fcap. 8vo.* 3*s.* 6*d.*

Also an edition on handmade paper, limited to 50 copies. *Large crown 8vo.* 10*s.* 6*d. net.*

'Mrs. Tomson holds perhaps the very highest rank among poetesses of English birth. This selection will help her reputation.'—*Black and White.*

Langbridge. A CRACKED FIDDLE. Being Selections from the Poems of FREDERIC LANGBRIDGE. With Portrait. *Crown 8vo.* 5*s.*

Langbridge. BALLADS OF THE BRAVE: Poems of Chivalry, Enterprise, Courage, and Constancy, from the Earliest Times to the Present Day. Edited, with Notes, by Rev. F. LANGBRIDGE. *Crown 8vo.*

Presentation Edition, 3*s.* 6*d.* School Edition, 2*s.* 6*d.*

'A very happy conception happily carried out. These "Ballads of the Brave" are intended to suit the real tastes of boys, and will suit the taste of the great majority. —*Spectator.* 'The book is full of splendid things.'—*World.*

History and Biography

Gladstone. THE SPEECHES AND PUBLIC ADDRESSES OF THE RT. HON. W. E. GLADSTONE, M.P. With Notes and Introductions. Edited by A. W. HUTTON, M.A. (Librarian of the Gladstone Library), and H. J. COHEN, M.A. With Portraits. *8vo. Vol. X.* 12*s.* 6*d.*

Russell. THE LIFE OF ADMIRAL LORD COLLINGWOOD. By W. CLARK RUSSELL, Author of 'The Wreck of the Grosvenor.' With Illustrations by F. BRANGWYN. *8vo.* 10*s.* 6*d.*

'A really good book.'—*Saturday Review.*

'A most excellent and wholesome book, which we should like to see in the hands of every boy in the country.'—*St. James's Gazette.*

Clark. THE COLLEGES OF OXFORD: Their History and their Traditions. By Members of the University. Edited by A. CLARK, M.A., Fellow and Tutor of Lincoln College. *8vo.* 12*s.* 6*d.*

'Whether the reader approaches the book as a patriotic member of a college, as an antiquary, or as a student of the organic growth of college foundation, it will amply reward his attention.'—*Times.*

'A delightful book, learned and lively.'—*Academy.*

'A work which will certainly be appealed to for many years as the standard book on the Colleges of Oxford.'—*Athenæum.*

Hulton. RIXAE OXONIENSES: An Account of the Battles of the Nations, The Struggle between Town and Gown, etc. By S. F. HULTON, M.A. *Crown 8vo.* 5*s.*

James. CURIOSITIES OF CHRISTIAN HISTORY PRIOR TO THE REFORMATION. By CROAKE JAMES, Author of 'Curiosities of Law and Lawyers.' *Crown 8vo.* 7*s.* 6*d.*

Clifford. THE DESCENT OF CHARLOTTE COMPTON (BARONESS FERRERS DE CHARTLEY). By her Great-Granddaughter, ISABELLA G. C. CLIFFORD. *Small 4to.* 10*s.* 6*d. net.*

General Literature

Bowden. THE IMITATION OF BUDDHA: Being Quotations from Buddhist Literature for each Day in the Year. Compiled by E. M. BOWDEN. With Preface by Sir EDWIN ARNOLD. *Second Edition.* 16*mo.* 2*s.* 6*d.*

Ditchfield. OUR ENGLISH VILLAGES: Their Story and their Antiquities. By P. H. DITCHFIELD, M.A., F.R.H.S., Rector of Barkham, Berks. *Post 8vo.* 2*s.* 6*d.* Illustrated.

'An extremely amusing and interesting little book, which should find a place in every parochial library.'—*Guardian.*

Ditchfield. OLD ENGLISH SPORTS. By P. H. DITCHFIELD, M.A. *Crown 8vo.* 2*s.* 6*d.* Illustrated.

'A charming account of old English Sports.'—*Morning Post.*

Burne. PARSON AND PEASANT: Chapters of their Natural History. By J. B. BURNE, M.A., Rector of Wasing. *Crown 8vo.* 5*s.*

'"Parson and Peasant' is a book not only to be interested in, but to learn something from—a book which may prove a help to many a clergyman, and broaden the hearts and ripen the charity of laymen."'—*Derby Mercury.*

Massee. A MONOGRAPH OF THE MYXOGASTRES. By G. MASSEE. *8vo.* 18*s. net.*

Cunningham. THE PATH TOWARDS KNOWLEDGE: Essays on Questions of the Day. By W. CUNNINGHAM, D.D., Fellow of Trinity College, Cambridge, Professor of Economics at King's College, London. *Crown 8vo.* 4*s.* 6*d.*

Essays on Marriage and Population, Socialism, Money, Education, Positivism, etc.

Anderson Graham. NATURE IN BOOKS: Studies in Literary Biography. By P. ANDERSON GRAHAM. *Crown 8vo.* 6*s.*

The chapters are entitled: I. 'The Magic of the Fields' (Jefferies). II. 'Art and Nature' (Tennyson). III. 'The Doctrine of Idleness' (Thoreau). IV. 'The Romance of Life' (Scott). V. 'The Poetry of Toil' (Burns). VI. 'The Divinity of Nature' (Wordsworth).

Works by S. Baring Gould.

Author of 'Mehalah,' etc.

OLD COUNTRY LIFE. With Sixty-seven Illustrations by W. PARKINSON, F. D. BEDFORD, and F. MASEY. *Large Crown 8vo, cloth super extra, top edge gilt,* 10*s.* 6*d. Fourth and Cheaper Edition.* 6*s.* [*Ready.*

'"Old Country Life," as healthy wholesome reading, full of breezy life and movement, full of quaint stories vigorously told, will not be excelled by any book to be published throughout the year. Sound, hearty, and English to the core.'—*World.*

HISTORIC ODDITIES AND STRANGE EVENTS. *Third Edition, Crown 8vo.* 6*s.*

'A collection of exciting and entertaining chapters. The whole volume is delightful reading.'—*Times.*

FREAKS OF FANATICISM. (First published as Historic Oddities, Second Series.) *Third Edition. Crown 8vo.* 6*s.*

'Mr. Baring Gould has a keen eye for colour and effect, and the subjects he has chosen give ample scope to his descriptive and analytic faculties. A perfectly fascinating book.—*Scottish Leader.*

SONGS OF THE WEST: Traditional Ballads and Songs of the West of England, with their Traditional Melodies. Collected by S. BARING GOULD, M.A., and H. FLEETWOOD SHEPPARD, M.A. Arranged for Voice and Piano. In 4 Parts (containing 25 Songs each), *Parts I., II., III.,* 3*s. each. Part IV.,* 5*s. In one Vol., roan,* 15*s.*

'A rich and varied collection of humour, pathos, grace, and poetic fancy.'—*Saturday Review.*

YORKSHIRE ODDITIES AND STRANGE EVENTS. *Fourth Edition. Crown 8vo.* 6*s.*

SURVIVALS AND SUPERSTITIONS. *Crown 8vo.* Illustrated. [*In the press.*

JACQUETTA, and other Stories. *Crown 8vo.* 3*s.* 6*d. Boards,* 2*s.*

ARMINELL: A Social Romance. *New Edition. Crown 8vo.* 3*s.* 6*d. Boards,* 2*s.*

'To say that a book is by the author of "Mehalah" is to imply that it contains a story cast on strong lines, containing dramatic possibilities, vivid and sympathetic descriptions of Nature, and a wealth of ingenious imagery. All these expectations are justified by "Arminell."'—*Speaker.*

URITH: A Story of Dartmoor. *Third Edition. Crown 8vo.* 3*s.* 6*d.*

'The author is at his best.'—*Times.*

'He has nearly reached the high water-mark of "Mehalah."'—*National Observer.*

MARGERY OF QUETHER, and other Stories. *Crown 8vo.* 3*s.* 6*d.*

IN THE ROAR OF THE SEA: A Tale of the Cornish Coast. *New Edition.* 6*s.*

Fiction

Author of 'Indian Idylls.' IN TENT AND BUNGALOW: Stories of Indian Sport and Society. By the Author of 'Indian Idylls.' *Crown 8vo.* 3*s.* 6*d.*

Fenn. A DOUBLE KNOT. By G. MANVILLE FENN, Author of 'The Vicar's People,' etc. *Crown 8vo.* 3*s.* 6*d.*

Pryce. THE QUIET MRS. FLEMING. By RICHARD PRYCE, Author of 'Miss Maxwell's Affections,' etc. *Crown 8vo.* 3*s.* 6*d.* *Picture Boards*, 2*s.*

Gray. ELSA. A Novel. By E. M'QUEEN GRAY. *Crown 8vo.* 6*s.*

'A charming novel. The characters are not only powerful sketches, but minutely and carefully finished portraits.'—*Guardian.*

Gray. MY STEWARDSHIP. By E. M'QUEEN GRAY. *Crown 8vo.* 3*s.* 6*d.*

Cobban. A REVEREND GENTLEMAN. By J. MACLAREN COBBAN, Author of 'Master of his Fate,' etc. *Crown 8vo.* 4*s.* 6*d.*

'The best work Mr. Cobban has yet achieved. The Rev. W. Merrydew is a brilliant creation.'—*National Observer.*

'One of the subtlest studies of character outside Meredith.'—*Star.*

Lyall. DERRICK VAUGHAN, NOVELIST. By EDNA LYALL, Author of 'Donovan.' *Crown 8vo.* 31*st Thousand.* 3*s.* 6*d.*; *paper*, 1*s.*

Linton. THE TRUE HISTORY OF JOSHUA DAVIDSON, Christian and Communist. By E. LYNN LINTON. Eleventh and Cheaper Edition. *Post 8vo.* 1*s.*

Grey. THE STORY OF CHRIS. By ROWLAND GREY, Author of 'Lindenblumen,' etc. *Crown 8vo.* 5*s.*

Dicker. A CAVALIER'S LADYE. By CONSTANCE DICKER. *With Illustrations. Crown 8vo.* 3*s.* 6*d.*

Dickinson. A VICAR'S WIFE. By EVELYN DICKINSON. *Crown 8vo.* 6*s.*

Prowse. THE POISON OF ASPS. By R. ORTON PROWSE. *Crown 8vo.* 6*s.*

Taylor. THE KING'S FAVOURITE. By UNA TAYLOR. *Crown 8vo.* 6*s.*

Novel Series

3/6

MESSRS. METHUEN will issue from time to time a Series of copyright Novels, by well-known Authors, handsomely bound, at the above popular price of three shillings and sixpence. The first volumes (ready) are :—

1. THE PLAN OF CAMPAIGN. By F. MABEL ROBINSON.
2. JACQUETTA. By S. BARING GOULD, Author of 'Mehalah, etc.
3. MY LAND OF BEULAH. By Mrs. LEITH ADAMS (Mrs. De Courcy Laffan).
4. ELI'S CHILDREN. By G. MANVILLE FENN.
5. ARMINELL: A Social Romance. By S. BARING GOULD, Author of 'Mehalah,' etc.
6. DERRICK VAUGHAN, NOVELIST. With Portrait of Author. By EDNA LYALL, Author of 'Donovan,' etc.
7. DISENCHANTMENT. By F. MABEL ROBINSON.
8. DISARMED. By M. BETHAM EDWARDS.
9. JACK'S FATHER. By W. E. NORRIS.
10. MARGERY OF QUETHER. By S. BARING GOULD.
11. A LOST ILLUSION. By LESLIE KEITH.
12. A MARRIAGE AT SEA. By W. CLARK RUSSELL.
13. MR. BUTLER'S WARD. By F. MABEL ROBINSON.
14. URITH. By S. BARING GOULD.
15. HOVENDEN, V.C. By F. MABEL ROBINSON.

Other Volumes will be announced in due course.

NEW TWO-SHILLING EDITIONS 2/-

Crown 8vo, Ornamental Boards.

ARMINELL. By the Author of 'Mehalah.'
ELI'S CHILDREN. By G. MANVILLE FENN.
DISENCHANTMENT. By F. MABEL ROBINSON.
THE PLAN OF CAMPAIGN. By F. MABEL ROBINSON.
JACQUETTA. By the Author of 'Mehalah.'

Picture Boards.

A DOUBLE KNOT. By G. MANVILLE FENN.
THE QUIET MRS. FLEMING. By RICHARD PRYCE.
JACK'S FATHER. By W. E. NORRIS.
A LOST ILLUSION. By LESLIE KEITH.

Books for Boys and Girls

Walford. A PINCH OF EXPERIENCE. By L. B. WALFORD, Author of 'Mr. Smith.' With Illustrations by GORDON BROWNE. *Crown 8vo.* 6*s.*

'The clever authoress steers clear of namby-pamby, and invests her moral with a fresh and striking dress. There is terseness and vivacity of style, and the illustrations are admirable.'—*Anti-Jacobin.*

Molesworth. THE RED GRANGE. By Mrs. MOLESWORTH, Author of 'Carrots.' With Illustrations by GORDON BROWNE. *Crown 8vo.* 6*s.*

'A volume in which girls will delight, and beautifully illustrated.'—*Pall Mall Gazette.*

Clark Russell. MASTER ROCKAFELLAR'S VOYAGE. By W. CLARK RUSSELL, Author of 'The Wreck of the Grosvenor,' etc. Illustrated by GORDON BROWNE. *Crown 8vo.* 3*s.* 6*d.*

'Mr. Clark Russell's story of "Master Rockafellar's Voyage" will be among the favourites of the Christmas books. There is a rattle and "go" all through it, and its illustrations are charming in themselves, and very much above the average in the way in which they are produced.—*Guardian.*

Author of 'Mdle. Mori.' THE SECRET OF MADAME DE Monluc. By the Author of 'The Atelier du Lys,' 'Mdle. Mori.' *Crown 8vo.* 3*s.* 6*d.*

'An exquisite literary cameo.'—*World.*

Manville Fenn. SYD BELTON: Or, The Boy who would not go to Sea. By G. MANVILLE FENN, Author of 'In the King's Name,' etc. Illustrated by GORDON BROWNE. *Crown 8vo.* 3*s.* 6*d.*

'Who among the young story-reading public will not rejoice at the sight of the old combination, so often proved admirable—a story by Manville Fenn, illustrated by Gordon Browne! The story, too, is one of the good old sort, full of life and vigour, breeziness and fun. —*Journal of Education.*

Parr. DUMPS. By Mrs. PARR, Author of 'Adam and Eve,' 'Dorothy Fox,' etc. Illustrated by W. PARKINSON. *Crown 8vo.* 3*s.* 6*d.*

'One of the prettiest stories which even this clever writer has given the world for a long time.'—*World.*

Meade. A GIRL OF THE PEOPLE. By L. T. MEADE, Author of 'Scamp and I,' etc. Illustrated by R. BARNES. *Crown 8vo.* 3*s.* 6*d.*

'An excellent story. Vivid portraiture of character, and broad and wholesome lessons about life.'—*Spectator.*

'One of Mrs. Meade's most fascinating books.'—*Daily News.*

Meade. HEPSY GIPSY. By L. T. MEADE. Illustrated by EVERARD HOPKINS. *Crown 8vo,* 2*s.* 6*d.*

'Mrs. Meade has not often done better work than this.'—*Spectator.*

Meade. THE HONOURABLE MISS: A Tale of a Country Town. By L. T. MEADE, Author of 'Scamp and I,' 'A Girl of the People,' etc. With Illustrations by EVERARD HOPKINS. *Crown 8vo,* 3*s.* 6*d.*

Adams. MY LAND OF BEULAH. By MRS. LEITH ADAMS. With a Frontispiece by GORDON BROWNE. *Crown 8vo,* 3*s.* 6*d.*

English Leaders of Religion

Edited by A. M. M. STEDMAN, M.A. *With Portrait, crown 8vo,* 2*s.* 6*d.*

A series of short biographies, free from party bias, of the most prominent leaders of religious life and thought in this and the last century. 2/6

The following are already arranged—

CARDINAL NEWMAN. By R. H. HUTTON. [*Ready.*

'Few who read this book will fail to be struck by the wonderful insight it displays into the nature of the Cardinal's genius and the spirit of his life.'—WILFRID WARD, in the *Tablet.*

'Full of knowledge, excellent in method, and intelligent in criticism. We regard it as wholly admirable.'—*Academy.*

JOHN WESLEY. By J. H. OVERTON, M.A. [*Ready.*

'It is well done: the story is clearly told, proportion is duly observed, and there is no lack either of discrimination or of sympathy.'—*Manchester Guardian.*

BISHOP WILBERFORCE. By G. W. DANIEL, M.A. [*Ready.*

CHARLES SIMEON. By H. C. G. MOULE, M.A. [*Ready.*

JOHN KEBLE. By W. LOCK, M.A. [*Nov.*

F. D. MAURICE. By COLONEL F. MAURICE, R.E.

THOMAS CHALMERS. By Mrs. OLIPHANT.

CARDINAL MANNING. By A. W. HUTTON, M.A. [*Ready.*

Other volumes will be announced in due course.

University Extension Series

A series of books on historical, literary, and scientific subjects, suitable for extension students and home reading circles. Each volume will be complete in itself, and the subjects will be treated by competent writers in a broad and philosophic spirit.

Edited by J. E. SYMES, M.A.,
Principal of University College, Nottingham.

Crown 8vo. 2*s.* 6*d.* 2/6

The following volumes are ready:—

THE INDUSTRIAL HISTORY OF ENGLAND. By H. DE B. GIBBINS, M.A., late Scholar of Wadham College, Oxon., Cobden Prizeman. *Second Edition.* With Maps and Plans. [*Ready.*

'A compact and clear story of our industrial development. A study of this concise but luminous book cannot fail to give the reader a clear insight into the principal phenomena of our industrial history. The editor and publishers are to be congratulated on this first volume of their venture, and we shall look with expectant interest for the succeeding volumes of the series.'—*University Extension Journal.*

A HISTORY OF ENGLISH POLITICAL ECONOMY. By L. L. PRICE, M.A., Fellow of Oriel College, Oxon.

PROBLEMS OF POVERTY: An Inquiry into the Industrial Conditions of the Poor. By J. A. HOBSON, M.A.

VICTORIAN POETS. By A. SHARP.

THE FRENCH REVOLUTION. By J. E. SYMES, M.A.

PSYCHOLOGY. By F. S. GRANGER, M.A., Lecturer in Philosophy at University College, Nottingham.

THE EVOLUTION OF PLANT LIFE: Lower Forms. By G. MASSEE, Kew Gardens. With Illustrations.

AIR AND WATER. Professor V. B. LEWES, M.A. Illustrated.

THE CHEMISTRY OF LIFE AND HEALTH. By C. W. KIMMINS, M.A. Camb. Illustrated.

THE MECHANICS OF DAILY LIFE. By V. P. SELLS, M.A. Illustrated.

ENGLISH SOCIAL REFORMERS. H. DE B. GIBBINS, M.A.

ENGLISH TRADE AND FINANCE IN THE SEVENTEENTH CENTURY. By W. A. S. HEWINS, B.A.

The following volumes are in preparation :—

NAPOLEON. By E. L. S. HORSBURGH, M.A. Camb., U. E. Lecturer in History.

ENGLISH POLITICAL HISTORY. By T. J. LAWRENCE, M.A., late Fellow and Tutor of Downing College, Cambridge, U. E. Lecturer in History.

AN INTRODUCTION TO PHILOSOPHY. By J. SOLOMON, M.A. Oxon., late Lecturer in Philosophy at University College, Nottingham.

THE EARTH: An Introduction to Physiography. By E. W. SMALL, M.A.

Social Questions of To-day

Edited by H. DE B. GIBBINS, M.A.

Crown 8vo, 2s. 6d. 2/6

A series of volumes upon those topics of social, economic, and industrial interest that are at the present moment foremost in the public mind. Each volume of the series will be written by an author who is an acknowledged authority upon the subject with which he deals.

The following Volumes of the Series are ready :—

TRADE UNIONISM—NEW AND OLD. By G. HOWELL, M.P., Author of 'The Conflicts of Capital and Labour.